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Measurement Techniques

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SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

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11th GENERAL CONFERENCE ON WEIGHTS AND MEASURES

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 1-4,
November, 1960

The present state of science and technology requires further efforts in order to ensure international uniformity of measuring units and standards which serve to reproduce them, and to raise the accuracy of the standards. It is precisely these questions which were discussed at the 11th General Conference on Weights and Measures held in Paris on October 11 to 20, 1960.

Of the 36 countries which adhere to the Metric Convention, 32 sent their representatives to the conference, including: USSR, USA, India, Britain, France, Bulgaria, Hungary, Poland, Rumania, Czechoslovakia and others. Unfortunately representatives of the German Democratic Republic could not take part in the conference since they were refused visas. The Soviet and Czech delegations issued a declaration at the conference condemning the discrimination exercised by the French Ministry of Foreign Affairs, which violated the rules governing the international organization set up by the Metric Convention.

The president of the International Committee of Weights and Measures, Academician Danjon (France) reported on the work carried out by the Committee of the International Bureau of Weights and Measures for the last six years since the 10th General Conference. This report dealt with the work carried out by the laboratories of the International Bureau of Weights and Measures, the international comparison of standards, the activity of the consultative committees, and decisions taken on international metrological questions by the International Committee of Weights and Measures.

A resolution proposed by the Soviet and Rumanian delegations approving the useful work carried out by the International Committee of Weights and Measures during 1954-1960 was carried by the conference. Taking into account that the spreading of the metric system encourages the development of science and modern technique, the conference calls in this resolution upon countries which have not yet joined the Metric Convention, and especially the countries which have recently gained their independence, to join the Convention as soon as possible, and recommends all the member-countries to use their scientific and technical influence in order to persuade other countries to join the Convention.

The Conference discussed in detail the problem of ensuring international uniformity in the sphere of ionizing radiation measurements.

Taking into account that international uniformity in measuring basic physical quantities has been successfully achieved and maintained for the last 85 years owing to the activity of the International Committee and the International Bureau of Weights and Measures, the conference decided to entrust the International Committee of Weights and Measures to organize in the International Bureau of Weights and Measures a department of standards for measuring ionizing radiations, establishing reference units and uniformity of measurements, with due consideration of the work of its own laboratories and that of other national and international organizations.

At the same time the conference passed a resolution establishing special contributions by member-states for the construction and equipment of these laboratories and decided to start immediately, without waiting for the completion of this construction, work for ensuring international uniformity of units and standards for measuring ionizing radiations, including all-round international comparison of national standards in this sphere. The conference entrusted the International Bureau of Weights and Measures to undertake the storing of the international standard of radium, which was received from the Radium Institute of the Paris University.

The conference received the report of the Consultative Committee on Standards for measuring ionizing radiations, in which a program of work was set out for the near future, including the establishment of four working parties: 1) on standards for x-ray and gamma radiations; 2) on standards for radioactive preparations; 3) on

standards for neutron sources, and 4) on radium standards; it is also planned to make in 1961 all-round comparisons of ionization chambers and reference radiation sources.

The 11th General conference carried out important preparatory work for transition to a new determination of the meter by means of light wavelengths. On October 14, 1960, the conference adopted, on the basis of the report by the Consultative Committee for determining the meter, a resolution which was proposed by the International Committee of Weights and Measures:

"Taking into consideration that the international prototype does not determine the meter with sufficient accuracy for the requirements of modern metrology, and that it is desirable to establish a natural and indestructible standard, the 11th General Conference on Weights and Measures decided that:

"1. The meter is a length equal to 1,650,763.73 wavelengths in vacuum, corresponding to the transition of a krypton 86 atom between levels $2p_{10}$ and $5d_5$.

"2. The determination of the meter, operative since 1889, based on an international platinum-iridium prototype is cancelled.

"3. The international meter prototype established by the 1889 General Conference on Weights and Measures shall be preserved by the International Bureau of Weights and Measures under the same conditions as those established in 1889."

At the same time the conference entrusted the International Committee to work out instructions for a practical determination of the meter and to continue its investigation for improving the standards of length. The proposal made by the Soviet delegation on selecting secondary wavelength standards for interferometer measurements of length and on drafting instructions for their application was also adopted by the conference.

In conformity with this resolution the International Committee of Weights and Measures has already drafted an instruction for the practical application of the newly defined meter by means of a tube with krypton 86.

The new definition of the meter not only re-established its value in terms of a natural indestructible unit, but also considerably (approximately by two orders) raised its accuracy. It was possible by means of the graduation on the platinum-iridium meter prototype to make comparisons with the reference meter with an error of the order of 0.1-0.2 μ, whereas now it is possible to make comparisons by means of the interferometer method and monochromatic radiations with an error of 0.001 μ, which satisfies much better the requirements of modern engineering and instrument-making.

The General Conference confirmed the decision of the International Committee of Weights and Measures taken at its 1956 session on the new determination of a unit of time, which was made necessary because the former definition of a second as 1/86400 of a mean solar day does not provide the required accuracy, in view of the irregularities of the earth's rotation round its axis.

The new determination of the second states:

"The second is 1/31556925.9747 of a tropical year for 1900, January 0 at 12 hr by the ephemeris time."

This determination of the second expresses it in terms of the rotation of the earth round the sun instead of about its axis and takes as a standard of time the duration of a tropical year, i.e., the time interval between two vernal solstices which follow one another.

The reference to 1900 is due to the fact that a tropical year is not constant, and therefore it was necessary to take a given year as a standard. The date "1900, January 0 at 12 hr" is expressed in the manner adopted in astronomy for counting time and corresponds to midday December 31, 1899.

In view of the results obtained in recent years by a number of laboratories in their experiments, which showed that a time-interval standard, based on the transition of atoms or molecules between two energy levels, can be established and reproduced with great accuracy, and that such an atomic time-interval standard is necessary for the requirements of precision metrology, the session adopted a second resolution which urges the national laboratories and international specialists in this sphere to continue their investigations as energetically as possible. The International Committee of Weights and Measures was instructed to co-operate with the interested international organizations, and co-ordinate this work in order to be able to arrive at a decision on this question at the XII General Conference on Weights and Measures.

The conference heard reports on the work carried out by several national laboratories and the International Bureau of Weights and Measures on absolute measurements of acceleration of gravity and adopted in this connection the following resolution:

"Taking account of the progress made in absolute measurements of the acceleration of gravity owing to the work of the International Bureau of Weights and Measures and several national laboratories, and noting at the same time that many important determinations have not yet been completed, the 11th General Conference on Weights and Measures decided temporarily to preserve the so-called Potsdam gravimetric system; it urges the International Bureau and national laboratories to continue their measurements; it empowers the International Committee of Weights and Measures to change the Potsdam system as soon as it finds that the values obtained for the acceleration of gravity are sufficiently accurate."

The conference heard the report of the President of the Consultative Committee for Thermometry and approved an amended text proposed by the Consultative Committee and attached to the definition of the international practical temperature scale of 1948 (amended in 1960).

Besides minor corrections the basic change in this text is as follows:

1) Abbreviation of the chapter entitled "Introduction" by excluding from it paragraphs of purely historical interest which are no longer relevant.

2) Substitution of the melting point of ice by the triple point of water and the assignment to it of a temperature of +0.01°C (International, 1948).

3) Cancelling the difference between "basic reference points" and "primary reference points" and the adoption of the term of "reference points for determining."

4) Unification of the equations which appear in the text, so as to make them equations of quantities and not numerical values.

5) Adoption of symbols T and $\underline{t}$ for denoting the thermodynamic temperatures of Kelvin and Celsius and symbols T_{int} and t_{int} for denoting international temperatures of Kelvin and Celsius.

6) Preserving the boiling point of sulphur as a reference point for determining the scale, but recommending to use the solidification point of zinc with a value of 419.505°C (International, 1948), since this point makes it possible to establish the same scale by more easily reproducible means.

Since all these changes refer only to the text and not to the determination of the scale, the former data has been preserved in its name, and the scale is known as "International Practical Temperature Scale, 1948."

Taking into consideration that the cubic decimeter and a liter are not equal to each other and differ by about 28-millionths, and that the determination of physical quantities which include the measurement of volume is increasing in accuracy, and thus intensifies the possible confusion between a cubic decimeter and a liter, the conference instructs the International Commitee of Weights and Measures to study this problem and present its report to the XII General Conference on Weights and Measures.

The conference heard the report of the commission of the International Committee of Weights and Measures on the system of units and decided to confirm the international system of units.

Taking into consideration resolution 6 of the Tenth General Conference on Weights and Measures, which adopted six units as the basis for establishing a practical international system of units, and resolution 3 adopted by the International Committee of Weights and Measures in 1956 on the establishment of an international system of units, as well as resolution 3 adopted by the International Committee of Weights and Measures in 1958 and referring to abbreviations in the system notations and to prefixes for forming multiple and fractional units, the conference decided:

"1. To call the system, founded on six basic units, 'International System of Units.'

"2. To establish an international abbreviation for this system as 'SI.'

"3. To form multiple and fractional units by means of the following prefixes. *

* The table of prefixes for forming multiple and fractional units adopted at the conference is given in supplement 2 on p. 919 of this issue (Editorial note).

"4. The following units shall be used in this system, without prejudice to other units which may be added subsequently."*

The conference heard reports of the Consultative Committees on Electricity and Photometry, including data on their sessions, adopted resolutions, as well as results of international comparisons of electrical and light standards conducted between 1954 and 1960.

Organizational questions occupied an important part in the work of the conference.

Since the previous general conference the International Committee of Weights and Measures had organized the commission for the revision of the Metric Convention. This convention, which was signed in 1875 and slightly modified in 1921, has become obsolete in certain parts and does not completely correspond to modern aims of an international organization of weights and measures.

In 1956-1959 the commission for revising the Metric Convention held several sessions and worked out its first draft plan for changing the convention, which provided for extending the activity of the International Bureau of Weights and Measures to all the spheres of physical measurements, for a more precise definition of the activity of the International Committee of Weights and Measures, for changing the allocation of contributions for the maintenance of the International Bureau, etc. These draft amendments were sent in February, 1960 to the governments of all the countries adhering to the Metric Convention for their consideration. During July to September, 1960, various observations on the draft were received from several countries, and the General Conference appointed at its first session a working party for examining these observations and formulating on their basis its proposals.

Having examined at its concluding session the report of the working party, the General Conference noted that it was impossible to reach an agreement on the required amendments to the Metric Convention, and it entrusted the International Committee of Weights and Measures to continue its work on this problem in order to prepare as soon as possible a draft which could be approved by the contracting countries.

The conference has examined and resolved the question of changing the allocation of contributions by member-states for the maintenance of the International Bureau of Weights and Measures. The existing allocation of contributions, which was established as long ago as 1875, was based on the population of countries and had a ratio of 1:30 between the minimum contribution of countries with a small population and the maximum contribution of countries with a population exceeding 100 millions. The General Conference adopted a new allocation based on the factors of the UN scale for individual countries, with a minimum of 0.5% and a maximum of 10% of the total contributions (i.e., with a ratio of contributions of 1:20).

The conference examined the question of the total contributions of member-states for the maintenance of the International Bureau and the International Committee of Weights and Measures. Taking into consideration that the required accuracy of measurements, with which the International Bureau is entrusted, is constantly rising and requires expensive instruments, that the sphere of the Bureau's activity has been extended to include standards for measuring ionizing radiations, and that all this activity must be carried out by highly qualified scientific personnel, the General Conference has decided to fix the total contributions of the member-states of the organization at 900,000 gold francs.

In conclusion, according to the regulation affixed to the Metric Convention, the conference re-elected half the members of the International Committee of Weights and Measures.

The XI General Conference on Weights and Measures has taken important decisions in a number of basic metrological questions of an international character and become an important step in the development of cooperation between countries for providing international uniformity in the sphere of measuring units and standards and for raising their accuracy.

* The table of units of the International System adopted by the XI General Conference is given in supplement 1 on p. 918 of this issue (Editorial note).

INTERNATIONAL SYSTEM OF UNITS*

G. D. Burdun

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 4-8,
November, 1960

The International Committee of Weights and Measures submits for the approval of the XI General Conference on Weights and Measures its recommendation on the establishment of an international system of units including: the name of the system, its abbreviation, a list of additional and derived units with their names, designations and dimensions, prefixes to the basic and derived units required for forming multiple and fractional units. The basic units of the system were determined by decision of the X General Conference on Weights and Measures.

The establishment of an International System of Units, which is recommended for scientific and technical purposes, practical application, and in teaching, concludes the preparatory work which had lasted for many years and had as its aim the establishment of international uniformity in the sphere of measuring units.

The scientific and technical principles underlying the international system of units are described below, as well as the organizational aspects of the problem and the proposals of the commission on a system of units, approved by the International Committee of Weights and Measures.

Scientific and technical principles underlying the International System of Units. The establishment of units for measuring physical quantities by means of a system based on several fundamental units, from which the remaining units are derived, is the only rational method of establishing units for various quantities on the basis of scientific, technical and practical considerations.

The first system of units consisted of the metric system established in France at the end of the 18th century. It consisted of a set of interconnected units for measuring length, area, volume, capacity and mass, and was based on two fundamental units, the meter and the kilogram.

The concept of a system of units for measuring a wide range of physical quantities was suggested in 1832 by Gauss, who proposed a system based on three fundamental units (length, mass and time) called an absolute system of units. Gauss selected as basic units for his system the millimeter, milligram and second. Since then several systems of units for measuring physical quantities have been originated (the CGS system, established in 1881 by the International Electrotechnical Congress, the system based on the meter, kilogram-weight and second, which has been adopted in technology since the second half of the last century, the MKS system, originated by Giorgi in 1901, the MTS system introduced by French legislation in 1919, etc.).

The utilization of several different systems of units leads in practice to considerable difficulties connected with the conversion of numerical values of the measured quantities, constants, etc., from one system of units into the other, and the introduction of a large number of conversion factors. The establishment of a most rational single system of units, which could be recommended on an international scale has long been overdue.

The establishment of a rational system of units involves the solution of the following special problems:

a) deriving a system of independent physical equations which provide the relation between all the quantities required for the establishment of measuring units;

b) analyzing the system of equations and selecting the basic units of the system;

c) formation of derived units;

d) deriving multiple and fractional units.

Physical equations required for the formation of a system of units should satisfy the following requirements:

* Paper presented to the XI General Conference on Weights and Measures by the author in his capacity as the President of the Commission on a System of Units of the International Committee of Weights and Measures.

the equations should be independent and consistent and each one should contain at least two physical quantities; the equations should be suitable for selecting a system of units in which all the coefficients are dimensionless quantities.

In selecting the basic units of the system it is necessary: 1) to provide a coherent system of units, i.e., to select basic units which would produce derived units by multiplication or division without introducing numerical coefficients; 2) the selected basic units should be reproducible with the utmost accuracy; 3) the size of units (both basic and derived) should be convenient for practical purposes.

If we consider the establishment of a system of mechanical units based on a system of physical equations which relate the mechanical quantities we shall arrive at the conclusion that several such systems are suitable providing they include two or three units in various combinations. In this connection several systems were suggested, those of the LT type (based on units of length and time), of the LMT type (length, mass and time), of the LFT type (length, force and time), and other systems.

An analysis of these systems based on the above-mentioned conditions leads to the conclusion that the best system is of the LMT type. The LFT type system, which is at present used in technology, is considerably less suitable. The reproduction of a unit of force is several times less accurate than that of a unit of mass, and a derived unit of mass in that system would not be convenient. For practical purposes the most convenient basic units of the LMT type system are the meter, the kilogram and the second, which explains the selection by international metrological organizations and the standardization of the MKS system.

For heat measurements three basic units are insufficient; it is necessary to introduce a fourth unit specific for this sphere of measurements. Such a fourth unit is temperature and the system of thermal units is of the LMTΘ type, where Θ is the temperature. The unit of temperature can be determined in various ways, but the most convenient and rational with respect to the size of basic unit is the system of the meter, kilogram, second and degree Kelvin.

For electrical and magnetic measurements it is possible to construct a system of units based on the primary unit of length, mass, time and a unit of one of the electrical or magnetic quantities. For practical purposes the most convenient system consists of four basic units: the meter, kilogram, second and ampere (the MKSA system). This system provides the required relation with the mechanical units.

Acoustical measurements do not require additional units and in this sphere all the measurements can be carried out by means of the MKS system.

For measurements of light three basic units are sufficient, those of length, time and a third specific unit, that of luminous intensity. For measurements of light it is, therefore, possible to use a system of the LTI type, where I is the luminous intensity. For practical purposes the most convenient system for measuring light is that with the basic units of the meter, kilogram and candle.

For measurements in the sphere of ionizing radiations (x-ray and gamma radiations and radioactivity) no additional basic units are required (except the electrical unit) and the MKSA system can be applied. The International Commission for Radiological Units established the size and special names for the most common derived units: the radiation dose, absorbed dose and activity (the roentgen, rad and curie). In the MKSA system the derived unit of coulomb per kilogram (C/kg) is used for measuring the radiation dose; the joule per kilogram (J/kg) is used for measuring the absorbed dose, and 1/s is used for activity. The units adopted by the International Radiological Commission are: roentgen = $2.57976 \cdot 10^{-4}$ C/kg; rad = 0.01 J/kg; and curie = $3.7 \cdot 10^{10}$ 1/s.

In order to provide a single system of units for measurements in all the physical spheres it is most convenient to base the system on six fundamental units: length, mass, time, thermodynamic temperature, electrical current and luminous intensity. The most convenient units for this system from the point of view of their size are: the meter, kilogram, second, degree Kelvin, ampere and candle.

<u>Preparation, establishment and adoption of the International System of Units.</u> In 1913 at the V General Conference on Weights and Measures M. Guillaume, director of the International Bureau of Weights and Measures, read a paper on systems of units, paying special attention to the MKS system, and noting its advantages with respect to other systems, especially the fact that its units of work and power coincide with similar units in the practical system of electrical measurements. On the basis of this report the General Conference decided to entrust the International Committee of Weights and Measures with the study of various systems of units.

The following resolution of the International Union of Pure and Applied Physics was submitted in 1948 to the IX General Conference on Weights and Measures:

"a) The International Union of Pure and Applied Physics requests the International Committee of Weights and Measures to adopt for international relations an international practical system of units. It does not recommend that physicists should no longer use the CGS system.

"b) For this purpose the International Union of Pure and Applied Physics recommends the system based on the meter, kilogram (mass), second and another unit from the absolute practical system (to be established later).

"c) The unit of force in this system (i.e., the force which acting upon a mass of 1 kilogram produces an acceleration of 1 m/sec^2) should be called a newton."

Simultaneously the French government on the suggestion of the National Scientific and Permanent Bureau of Weights and Measures submitted to the General Conference its own draft proposal for the unification of the international measuring units. The basic proposals of the French draft consisted of the following:

"1. The basic units of length, mass and time should be the meter, kilogram (mass) and the second of solar time.

"2. The absolute units of the practical electrical system should be preserved in the form they were determined by the resolution of the International Committee of Weights and Measures in October 1946 and should now be incorporated in national legislation.

"3. Any system which has as a basic unit force or weight should be excluded. If it should be considered advisable to allow the use in engineering practice of a unit of weight, this unit should be given a special name which should not resemble the name or symbol of the metric system of mass."

The draft included a table of the MKSA units and a draft text of the law and regulation on measuring units.

Having discussed the above proposals the IX General Conference adopted the following resolution:

"Taking into consideration that the International Committee of Weights and Measures has received a request from the International Union of Pure and Applied Physics to adopt for international relations a practical international system of units, recommending the MKS system with one electrical unit of the absolute practical system and at the same time not recommending that physicists should no longer use the CGS system, and taking into consideration that the conference has received from the French government a similar request with an appended draft resolution intended to serve as a basis of discussion for establishing comprehensive legislation covering measuring units, the General Conference instructs the International Committee to:

"initiate by means of an official questionnaire the collection of opinions on this question from scientific, technical and pedagogic circles of all countries (submitting as a basis for consideration the French document) and to proceed energetically with this work;

"to classify the answers;

"and to formulate a recommendation regarding the establishment of a single practical system of measuring units acceptable to all the countries which have signed the Metric Convention."

The study by various countries of this problem and the submission of conclusions to the International Bureau of Weights and Measures took a longer time than was anticipated and when the X General Conference on Weights and Measures met in 1954 a full consideration of all the relevant material had not yet been completed.

Having discussed the problem of the International System of units the X General Conference adopted the following resolution:

"Conforming with the wish expressed by the Ninth General Conference in resolution No. 6 with respect to the establishment of a practical system of measuring units for international relations, the tenth General Conference on Weights and Measures has decided to adopt as the basis of this system the following units:

Length	Meter
Mass	Kilogram
time	second
electrical current	ampere
thermodynamic temperature	degree Kelvin
luminous intensity	candle."

This resolution laid the firm foundation for the international unification of measuring units. Simultaneously the International Committee of Weights and Measures appointed in 1954 a system of units commission, which consisted of seven members of the Committee and the director of the International Bureau of Weights and Measures.

During 1954-56 the consideration of the questionnaire undertaken according to the decision of the IX General Conference was completed.

The answers received from 21 countries showed that the suggested international unification of a system of measuring units met with an exceptionally favorable reception and all the comments referred to some specific points, mainly regarding the legislative part of the proposals.

The commission met in October 1956 during the current session of the International Committee of Weights and Measures.

The meeting discussed the answers to the questionnaire on the draft proposal for an international unified system of measuring units. The commission also examined a draft proposal of a list of additional and derived units formed on the basis of the decision on basic units adopted by the X General Conference.

The naming of the proposed system of units produced a lengthy discussion. Of the three versions under discussion, the "Giorgi system,"MKSADC system" (consisting of the initial letters of the six basic units of the system) and the "International System of Units," the commission unanimously decided to recommend the International Committee to adopt the latter name.

The commission decided to submit for the approval of the International Committee the first list of additional and derived units of the International System of Units, which consisted of two additional and twenty-eight derived units.

On October 6, 1956, the International Committee of Weights and Measures examined the proposal submitted by the commission and passed the following resolution:

"Taking into consideration the instruction of the IX General Conference on Weights and Measures, contained in its resolution No. 6, regarding the establishment of a practical system of measuring units acceptable to all the countries which have signed the Metric Convention; and taking into consideration all the documents received from twenty-one countries who answered the questionnaire proposed by the IX General Conference on Weights and Measures, and taking into consideration resolution No. 6 of the X General Conference on Weights and Measures, which selected the basic units of the future system, the Committee recommends that the system based on six fundamental units adopted by the X General Conference should be called the 'International System of Units'."

At the same time the list of recommended additional and derived units for the International System of Units was also adopted without prejudice to other units being subsequently added to the list.

The names of the derived units of the International System of Units were suggested according to the existing international recommendations. The adoption of the name "tesla" for the unit of magnetic induction corresponds to the decision of the international electrotechnical commission. At present Technical Committee No. 24 of the International Electrotechnical Commission is considering the proposal of the USSR to name the unit of the magnetic field strength "lenz." Since this question is still under consideration no name has as yet been given to this unit.

At its 1958 session the International Committee of Weights and Measures discussed and adopted a decision on the abbreviation of the name "International System of Units." A symbol consisting of two letters SI (initials of "Systeme International") was adopted. Moreover, this session of the International Committee added to the previously adopted prefixes for forming multiple and fractional units four new prefixes: tera, giga, nano, and pico, thus completing the table of prefixes for forming multiple and fractional units.

The establishment of an International System of Units on the basis of the six fundamental units adopted by the X General Conference on Weights and Measures was an important progressive act which unified the experience of scientific and technical circles in various countries and of international organizations in metrology, standardization, physics and electrical technology.

In 1956 the International Standardization Organization adopted the first international recommendation R 31, part I, for standardizing measuring units. This recommendation puts at the top of its list the system of units based on the six fundamental units adopted by the X General Conference on Weights and Measures and provisionally called the MKSA system. The first table given in this recommendation includes the basic units of the system, the meter, kilogram, second, ampere, degree Kelvin and candle.

In 1958 the International Committee of Legislative Metrology adopted the following resolution on the question of an international system of units:

"The International Committee of Legislative Metrology assembled at its plenary session in Paris on October 7, 1958, wishes to associate itself with the resolution of the International Committee of Weights and Measures on the establishment of an international system of measuring units.

"The basic units of this system should be: the meter, kilogram, second, ampere, degree Kelvin and candle.

"The Committee recommends its member-states to adopt this system in their legislation on measuring units."

Since 1955 several countries have adopted in their legislation or national standards the system of units recommended by the International Committee of Weights and Measures as an international system of units.

<u>Recommendations of the International Committee of Weights and Measures on the Question of an International System of Units, Submitted for Approval to the XI General Conference on Weights and Measures:</u>

<u>1. Name and abbreviated notation of the system.</u>

To adopt the name "International System of Units" for this system, based on six fundamental units: the meter, kilogram, second, degree Kelvin, ampere and candle.

To use for its abbreviation a symbol of SI.

<u>2. List of basic, additional and derived units.</u>

To adopt the following list of basic, additional and derived units of the International System of Units with their abbreviations and dimensions, without prejudice to other derived units which may be subsequently added to the list (see table in Appendix 1).

<u>3. Definition of the basic and dimensions of the derived units.</u>

The definitions of the basic units are given according to the decisions of the General Conferences on Weights and Measures (meter and second by the XI General Conference, kilogram by the III General Conference, ampere and candle by the IX General Conference, and degree Kelvin by the X General Conference). The dimensions of the derived units are given in the table of Appendix 1, and are expressed by means of the basic or additional and derived units.

<u>4. Formation of multiple and fractional units.</u>

To establish that multiple and fractional measuring units should be obtained by multiplying or dividing the units by powers of 10. Their names are obtained by adding the suffixes shown in the table of Appendix 2 to the names of the basic or derived units.

International System of Units*

Basic units

Length	meter	m
Mass	kilogram	kg
Time	second	s
Thermodynamic temperature	degree Kelvin	°K
Electric current intensity	ampere	A
Luminous intensity	candle	cd

Additional units

Plane angle	radian	rad
Solid angle	steradian	sr

Derived units

Area	square meter	m^2	
Volume	cubic meter	m^3	
Frequency	hertz	Hz	1/s
Volumetric mass (density)	kilogram per cubic meter	kg/m^3	
Velocity	meter per second	m/s	
Angular velocity	radian per second	rad/s	
Acceleration	meter per second squared	m/s^2	
Angular acceleration	radian per second squared	rad/s^2	
Force	newton	N	$kg \cdot m/s^2$
Pressure (mechanical tension)	newton per square meter	N/m^2	
Dynamic viscosity	newton-second per square meter	$N \cdot s/m^2$	
Kinematic viscosity	square meter per second	m^2/s	
Work, energy, amount of heat	joule	J	$N \cdot m$
Power	watt	W	J/s
Quantity of electricity	coulomb	C	$A \cdot s$
Electrical tension, potential difference, electromotive force	volt	V	W/A
Electrical field strength	volt per meter	V/m	
Electrical resistance	ohm	Ω	V/A
Capacitance	farad	F	$A \cdot s/V$
Magnetic flux	weber	Wb	$V \cdot s$
Inductance	henry	H	$V \cdot s/A$
Magnetic induction	tesla	T	Wb/m^2
Magnetic field strength	ampere per meter	A/m	
Magnetomotive force	ampere	A	
Luminous flux	lumen	lm	$cd \cdot sr$
Luminance	candle per square meter	cd/m^2	
Illuminance	lux	lx	lm/m^2

* In the USSR abridged names of measuring units, specified by appropriate standards, are now being used.

Appendix 2

Prefixes for forming multiple and fractional units

Factor by which units are multiplied	Prefix	Notation
$1\,000\,000\,000\,000 = 10^{12}$	tera	T
$1\,000\,000\,000 = 10^{9}$	giga	G
$1\,000\,000 = 10^{6}$	mega	M
$1\,000 = 10^{3}$	kilo	k
$100 = 10^{2}$	hecto	h
$10 = 10^{1}$	deka	da

Factor by which units are multiplied	Prefix	Notation
$0{,}1 = 10^{-1}$	deci	d
$0{,}01 = 10^{-2}$	centi	c
$0{,}001 = 10^{-3}$	milli	m
$0{,}\,000\,001 = 10^{-6}$	micro	μ
$0{,}\,000\,000\,001 = 10^{-9}$	nano	n
$0{,}\,000\,000\,000\,001 = 10^{-12}$	pico	p

CHECKING DIGITAL COUNTING INSTRUMENTS

E. F. Dolinskii

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 9-10,
November, 1960

A nominal representation of the test circuit is shown in the figure attached.

The difference in the pulse repetition phase of the reference and the checked instruments leads to the reference instrument always indicating a smaller number of pulses than should correspond to one pulse of the checked instrument. It is, of course, assumed that the pulse repetition frequency of the reference instrument is always larger than that of the checked instrument.

The corresponding error will lie in the limits of (−2; 0) when counting pulses, or in the limits (−2a; 0) if a is the variation of the measured quantity corresponding to the sending of one pulse or the interval between two pulses of the reference instrument.

Moreover, there are no reasons to believe that the phase difference, which is random for any given measurement, will tend to assume any preferred value within the above range (−2a; 0). Hence, the distribution of the phase difference and therefore of the error in the method of measurement should be assumed uniform in the above range.

Under these conditions the expectation value of the error in this method of measurement will be equal to (−1) in terms of pulses or to (−a) in terms of the units of the measured variable. The quadratic mean deviation will be $1/\sqrt{3}$ and $a/\sqrt{3}$ respectively.

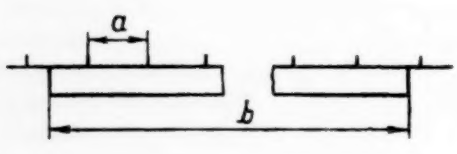
Checking should be done with the above expectation values of the error taken into consideration, i.e., an interval equal to one pulse of the tested instrument should be considered equal to (n + 1) intervals between the pulses of the reference instrument.

There is, obviously, no point in calculating any limiting errors based on any confidence probability when the distribution is uniform.

If we should, as indicated above, assume that

$$b = (n + 1)\, a \tag{1}$$

(b is the value of the measured variable which corresponds to the spacing between pulses of the tested instrument), the errors will be uniformly distributed in the range (−a; a), but the value of the quadratic mean error equal to $a/\sqrt{3}$ will remain the same.



Next we should examine the effect on the checking method error of the reference instrument pulse-repetition frequency.

If, according to the above reasoning, the value of b is determined by the formula

$$b = (n + 1)\, a_0, \tag{2}$$

in which a_0 represents the nominal value of the reference pulse duration, the error of b will be determined from the formula

$$\Delta b = b - b_0 = [(n+1)\, a_0 - b_0]. \tag{3}$$

The actual value of Δb will, however, be

$$\Delta b = b - b_0 = [(n+1)\,a_0 - b_0] + (n+1)\,\Delta a, \tag{4}$$

where Δa is the error of the reference instrument.

If we also take into account the additional error, mentioned above, we shall have

$$[(n+1)\,a_0 - b_0] + (n+1)\,\Delta a - a < \Delta b \leqslant [(n+1)\,a_0 - b_0] + (n+1)\,\Delta a + a. \tag{5}$$

Equations (4) and (5) show that it is advisable to raise the pulse repetition frequency of the reference instrument only to a certain extent. In fact, if we take two reference instruments with pulse durations a and c, and take

$$c_0 = \frac{1}{m}\,a_0,$$

then for an instrument with a pulse duration of c_0 an equation similar to (5) will be

$$[(n+1)\,mc_0 - b_0] + (n+1)\,m\Delta c - c < \Delta b < [(n+1)\,mc_0 - b_0] + (n+1)\,m\Delta c + c. \tag{6}$$

If the relative errors of quantities a and c are equal, i.e.,

$$\frac{\Delta a}{a_0} = \frac{\Delta c}{c_0},$$

then

$$(n+1)\,\Delta a = (n+1)\frac{a_0}{c_0}\Delta c = (n+1)\,m\Delta c.$$

Hence, the second components of the right-hand side of (5) and (6) are equal. It is only possible to decrease the error by reducing the third component, which in one instance is equal to a and in the other to c.

Thus, it is only advisable to raise the reference pulse repetition frequency up to a limit at which it is possible either to neglect or to reduce the third component to a permissible value.

It is only possible to reduce the error represented by term $(n+1)\,\Delta a$ by decreasing the relative error of the reference pulse duration:

$$(n+1)\,\Delta a = [(n+1)\,a_0]\,\frac{\Delta a}{a_0} = [(n+1)\,mc_0]\,\frac{\Delta c}{c_0}, \tag{7}$$

since its value for a given nominal pulse duration depends only on the relative errors

$$\frac{\Delta a}{a_0};\ \frac{\Delta c}{c_0}.$$

Evaluation of possible checking errors. The actual value of the tested instrument error $(b_\partial - b_0)$ will be

$$b_\partial - b_0 \simeq (n+1+k)\,a - b_0$$

or

$$b_\partial - b_0 \simeq [(n+1)\,a_0 - b_0] + (n+1)\,\Delta a + ka_0. \tag{8}$$

In checking, this error will be evaluated from the formula

$$b-b_0=(n+1)\,a_0-b_0. \tag{9}$$

From (8) and (9) we have

$$b-b_0=(b_\partial-b_0)-(n+1)\,\Delta a-ka_0,$$

or with new notations where $(b_\partial - b_0) = x$ is the error of the tested instrument; $-(n + 1)\,\Delta a = y$ is the error of the reference instrument; $-ka_0 = z$ is the error of the checking method, we shall have

$$b-b_0=x+y+z.$$

Hence the checking errors, i.e., scrapping good and passing defective instruments, will amount to [1]

$$W\% = \Big\{ 2\Big[\int_0^{\Delta x} p(x)\Big(\int_{\Delta x-x}^{\infty} p(y+z)\,d(y+z) + \int_{-\infty}^{-(x+\Delta x)} p(y+z)\,d(y+z)\Big)dx\Big] +$$

$$+2\int_{\Delta x}^{\infty} p(x)\Big[\int_{-(x+\Delta x)}^{-(x-\Delta x)} p(y+z)\,d(y+z)\Big]dx\Big\}\,100\,\%.$$

The distribution density of z may be taken as

$$p(z)=\frac{1}{2a}.$$

The distribution densities of quantities x and y should be determined in routine testing of the reference and the checked instruments, and the density $p(y + z)$ can be found by adding the distributions of the quantities y and z.

LITERATURE CITED

1. E. F. Dolinskii, Izmeritel'naya Tekhnika 3 (1958).*

* See English translation.

LINEAR MEASUREMENTS

APPLICATION OF WOOD-GRAINED PLASTICS FOR MAKING LARGE MEASURING INSTRUMENTS

L. M. Shereshevskii and A. M. Barskii

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November, 1960

The development of heavy presses in the last few years has produced a requirement for universal and special instruments for high precision checking of dimensions in the range of 500-3,000 mm.

This has led to the development and production by the Experimental Scientific Research Institute (ÉNIKMASh) of such instruments for the Voronezh forge and press manufacturing plants.

The main problem in manufacturing such instruments consists in reducing their weight and heat conductivity.

In order to meet these requirements it was decided to use for the body of these instruments a wood-grained plastic (WGP) for the following reasons.

The WGP is a cheap and readily available plastic; it is produced in the shape of large sheets (2,200 × × 950 mm, 5,400 × 1,200 mm), thus facilitating the manufacture of the greater part of the instrument bodies, which can be cut out by means of band saws; it has a low thermal conductivity, and a low specific gravity (1.25-1.3). The modulus of elasticity of WGP is higher than in wood of the hardest types. WGP is suitable for any type of machining.

Fig. 1.

WGP was used for making 500-1,200 mm lever micrometers; 2,000 mm try squares; 1,000-4,000 mm dial snap gauges; an instrument for measuring distances between axes up to 3,000 mm in mountings; instruments for checking the alignment of holes and external diameters in flywheels, gears, pulleys and other details; an instrument for checking the intersection of shaft axes at a distance of 500-2,000 mm; and an instrument for measuring crankshafts.

In order to determine their operational properties and their limiting error, tests were carried out on a 800-900 mm lever micrometer (Fig. 1) of weight 3.9 kg.

The limiting measurement error of a lever micrometer is

$$\Delta \lim = \sqrt{\Sigma \Delta_i^2} = \sqrt{\Delta_1^2 + \Delta_2^2 + \Delta_3^2 + \Delta_4^2 + \Delta_5^2},$$

where Δ_1 is the error in determining the length of the reference measure amounting to $\pm 5\mu$ (OST 85000-39); Δ_2 is the error of setting the snap gauge to size according to the Bureau of Interchangeability data, and it amounts to $\pm 10\mu$; Δ_3 is the error of the micrometer head, amounting to $\pm 4\mu$ (GOST 6507-53); Δ_4 is the error of the 0-5 mm displacement indicator, amounting to $\pm 15\mu$, providing the deviations do not exceed 1 mm (GOST 577-53); Δ_5 is the error of setting the contact, which according to N. N. Savin is equal to $\pm 15\mu$ [1].

After substitutions we obtain $\Delta\text{lim} = \pm 24\mu$.

The error of setting the displacement indicator to zero, the error of reading and temperature errors have not been considered owing to their negligible size as compared to the remaining errors.

The errors due to elastic deformations in determining Δlim have not been considered.

The use in the lever micrometer of an indicating head with a measuring effort of 400 g practically excludes any deformations of the snap gauge due to longitudinal stresses, since they affect the displacement indicator only and are not transmitted to the body of the gauge.

The value of the bending of the gauge is recorded in the micrometer certificate with the corresponding sign, and is taken into account when the micrometer has to be used in different positions for measuring various details.

In order to verify the analytical computations, the limiting error was checked by testing an experimental model.

TABLE 1

x_i, μ	n_i	nx_i μ	nx_i^2
−20	2	−40	800
−15	5	−75	1125
−10	9	−90	900
− 5	15	−75	375
0	44	0	0
+ 5	12	+60	300
+10	8	+80	800
+15	4	+60	900
+20	1	+20	400
	$N = 100$	$\Sigma nx_i = -60\ \mu$	$\Sigma nx_i^2 = 5600$

TABLE 2

Measurements limits, mm	Limiting errors in measuring details with a lever micrometer, μ	Tolerances in measuring details, μ				
		grade of accuracy				
		1	2	2a	3	3a
500– 600	±18	±13	±18	±28	±42	±70
600– 700	±20	±15	±20	±32	±45	±75
700– 800	±21	±15	±20	±32	±45	±75
800– 900	±22	±18	±22	±36	±50	±85
900–1000	±24	±18	±22	±36	±50	±85
1000–1200	±27	±20	±24	±40	±60	±95

Since it is impossible with the means available in a workshop to certify any detail over 500 mm with sufficient accuracy for comparative measurements, and it is impossible to measure such details on a measuring machine, a "fictitious" detail was made which consisted, in fact, of the two opposite sides of a detail. This was achieved in the following manner: the spindles and roller bearings in the body of the type IZM-10m measuring machine supports were replaced by special rollers with adjustable cylindrical caps.

The edges of these caps were placed on the line of measurement by means of set screws. The supports with the caps could be fixed at any distance from each other within the range of the machine, thus simulating a fictitious detail of any length with an accuracy of ± 0.001 mm. A constant measuring effort at the tail spindle of the measuring machine was insured by using a micrometer graduated in 0.001 mm.

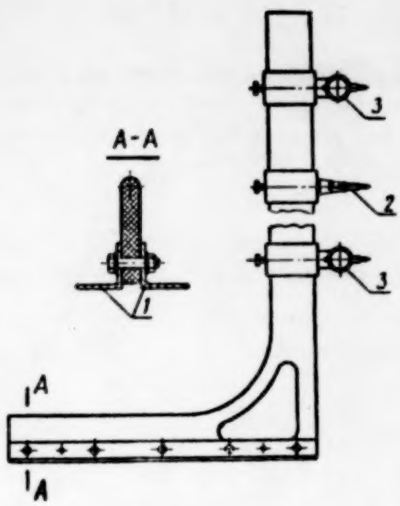

Fig. 2.

The lever micrometer was set by means of reference measures to various sizes, in order to measure the fictitious detail which was previously set to the same sizes.

In order to find the errors due to temperature variation the micrometer gauge was heated up to 20°C above the normal temperature, set to the same size and used to measure the same fictitious detail as before the heating. In order to exclude the effect of the micrometer's own weight on the measurements, the setting of the micrometer to a given size and subsequent measurement were made in the same position of the micrometer.

Thus all the conditions were provided for an experimental determination of the limiting error in this method of measuring details by means of an 800-900 mm lever micrometer.

Altogether 100 measurements were made.

Table 1 shows classified measurement results.

The mean value $\bar{x} = \Sigma n x_i / N = -0.6\ \mu$.

The dispersion $D(x) = (\Sigma n x_i^2 / N) - \bar{x}^2 = 55.64\ \mu$.

The quadratic mean error was

$$\sigma = \sqrt{D(x)} \simeq \pm 7.5\ \mu.$$

The limiting error of the measuring method was $\Delta\lim = 3\sigma = \pm 22.5\ \mu$.

Thus, the experimentally obtained limiting error of a sample lever micrometer is in good agreement with the analytical calculation and provides good ground for considering the latter to be reliable.

The limiting errors of lever micrometers of other sizes were determined by calculation.

The results thus obtained together with the tolerances for measuring details are shown in Table 2.

It will be seen from Table 2 that the WGP lever micrometers can be effectively used for measuring details starting with grade 2 accuracy under normal workshop conditions without observing strict temperature control.

For measuring details of the 1st grade of accuracy it is necessary: to use registering devices calibrated in 0.001 mm; to set for a nominal size only by means of reference or block gauges; to suspend the micrometer during measurements, thus completely eliminating deformations of the micrometer frame and facilitating the reading; carefully to keep the temperature of the reference measure and the detail at the same level.

Considerable difficulties arise in measuring perpendicularity of large details both in their manufacture and mounting.

Tolerances in the deviation from perpendicularity, for instance, of the press guide racks to the plane of the table or the forging base should not exceed 0.1-0.2 mm over a length of 2,000 mm.

The available metal try squares do not satisfy the above requirements either with respect to accuracy or rigidity. Moreover, they are inconvenient to use; it is sufficient to note that such a try square with a long side of 2,000 mm weighs over 60 kg, and has usually to be moved by means of a crane.

The new light try square which weighs 16 kg (Fig. 2) has a WGP frame, a metal resting surface of angle pieces 1, an adjustable rest 2 and two adjustable holders 3 for indicating instruments, one of which has a microscrew for setting the ends of the displacement indicators in a plane perpendicular to the resting surface.

This try square is set either on a test plate against a reference try square, or by means of a device consisting of a reference cylinder with a guide ruler attached to it, in the manner it is done in the press-manufacturing plant.

SUMMARY

The study of the above instruments and their testing under production conditions have shown the possibility and advisability of manufacturing universal and special instruments of a lighter type by using for their frames wood-grained plastics (WGP) for the purpose of checking with greater accuracy dimensions in the range of 500-3,000 mm.

LITERATURE CITED

1. N. N. Savin, Measurements of Large Details [Russian translation] (issued by the "Skoda" plant in 1944, translation NIBVMSS, Moscow, 1947).

CONTINUOUS CONTROL OF TAPERING IN DETAILS SHAPED ON CIRCULAR GRINDING MACHINES

S. G. Fateev

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In the final machining of details it is important not only to preserve accurate dimensions, but also to provide a correct geometrical form.

One of the types of irregularities in the geometrical form of smooth cylindrical surfaces consists of deviations from parallellism of its generating lines (tapering).

Tapering may arise owing to incorrect setting of the machine, or to the combined stresses and thermal deformations of the machine, the tool and the detail. Thus, for instance, it has been experimentally established that the temperature deformation in a circular grinding machine type 312M after seven hours'work results in a tapering over a length of 500 mm amounting to 70 μ for "passing" grinding and to 30 μ for cut-in grinding.

Owing to the relative importance of grinding operations, and to their finishing nature, automatic compensation of the errors in the shape of details acquires an immediate importance.

At present devices for automatic compensation of tapering are only commercially used in cut-in grinding operations.*

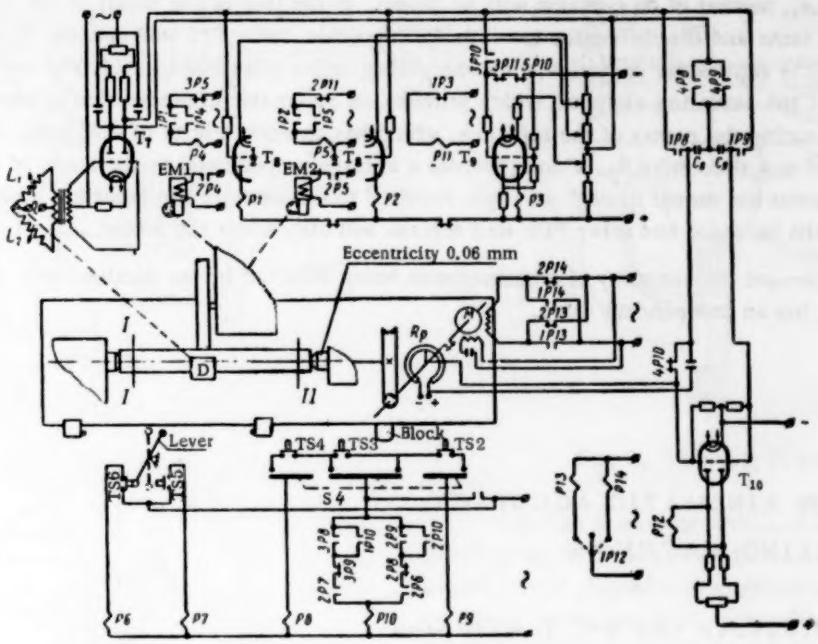
Below we give a schematic of the proposed device for automatic compensation of tapering in "passing" grinding.

The device (see figure) consists of the following units: an electrical unit with an induction measuring device; an actuating element which automatically compensates for tapering; actuating element which controls grinding conditions; and a distributing system.

The induction measuring device consists of a bracket with a differential induction transducer D connected to a bridge circuit.

When the detail is being machined the bridge remains unbalanced until the set dimensions of the detail are attained. The voltage at the output of the bridge, and hence the amplified voltage at the output of the phase detector T_7, will be proportional to the deviation of the detail size from the set value. The voltage is fed from the phase detector to the grids of tubes T_8 and T_9, whose anode circuits are connected to electronic relays P1 and P2 and trigger P3, which control the conditions of operation.

* Some of these devices are described in S. S. Volosov's paper entitled "Automatic Means of Ensuring Accuracy in Grinding." Mashgiz, Moscow, 1958.



When the correct size is reached, relay P1 operates, its contact 1P1 on closing energizes relay P4, whose operation energizes electromagnet EM1, which transfers the machine from rough to smooth grinding.

When the set size of the detail is reached, taking into account the allowance for finishing grinding, relay P2 operates, closes contact 1P2, energizes relay P5 and electromagnet EM2, which transfers the machine from smooth to finishing grinding.

When the final dimension of the detail is reached the electrical bridge becomes balanced, operates relay P3 and through its contact 1P3 energizes relay P11, which provides the required command for stopping machining. In order to prevent a "step" forming on the surface of the machined detail the withdrawal of the grinding headstock and switching off of the motor are not carried out immediately, but only at the end of the longitudinal travel of the table, i.e., when relays P6 and P7 de-energize. This can only occur at the end of the travel, when the switching lever leaves one of the switches and before it reaches the other (for instance, when switch TS6 is in the off position and before switch TS5 has been operated; this position of the lever is indicated on the drawing by a dotted line).

Since the trigger is set to operate when the bridge is balanced, the variations in the supply voltage and the nonlinearity of the transducer do not affect the accuracy of the dimensions of the machined details.

The tapering is checked and compensated automatically only during fine grinding in the following manner. A block is fixed to the machine table and three track switches TS2, TS3 and TS4 are fixed to the bedplate at a distance from each other of 100 and 200 mm. Thus the base for measuring the tapering can amount to 100, 200 and 300 mm. The required measuring base is adjusted by means of switch TS4. Thus, of the three track switches only two are operative.

When the detail is being machined and the table displaced longitudinally, the block operates consecutively the first and second switches, causing the size of the detail to be measured at cross sections I – I and II – II. When the track switch TS2 is operated, relay P9 is energized, its contacts 1P9 and 4P9 are closed and capacitor C_9 is charged to a voltage proportional to the deviations from the set size at cross section 1. When the end switch TS4 is operated (a base of 300 mm) relay P8 is energized, its contacts 1P8 and 4P8 are closed and capacitor C_8 is charged to a voltage proportional to the deviation from the set size at cross section 2.

After the operation of both track switches, relay P10 is released, its contacts 4P10 and 6P10 are closed and the voltage across capacitors C_8 and C_9 is fed to tube T_{10} to whose output a three-position polarized relay P12 is

connected. If the size of the detail at both cross sections is the same, the P12 relay armature will remain in the middle position, i.e., neither of its contacts will be closed. If the size of the detail in the first and second cross sections is not the same and the difference exceeds the tolerance, relay P12 will operate to one or the other side depending on the sign of the deviation, thus energizing either relay P13 or relay P14 and connecting the reversible motor of the actuating element, which provides an automatic compensation of tapering. Tapering is compensated by rotating the center of the tailstock, which has an eccentricity of 0.06 mm. The axle of the motor is connected to a slide-wire R_p, which provides a voltage proportional to the angle of rotation of the motor axle. When the motor has turned through an angle required to compensate the tapering, both voltages on the grids of tube T_{10} will be equal and relay P12 will release and disconnect the motor.

In order to prevent the accuracy of measurements being affected by the friction force of the system, the actuating element has an independent drive.

CHECKING THE KINEMATIC ACCURACY OF GEAR-CUTTING MACHINES

L. V. Drozdova and Kh. I. Libenson

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The method of checking the kinematic accuracy of gear-cutting machines described in this article is based on determining the degree of coordination in the working of the dividing and burnishing chains which connect the tool spindle to the table of the machine.

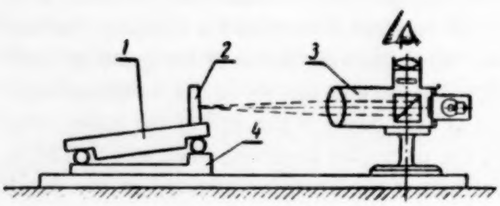

Fig. 1.

This method does not require the use of special instruments and makes it possible to determine by means of simple devices and calculation the maximum kinematic error in the link between the cutter and the table for one turn of the table, to estimate its backlash, and to determine the maximum error in the link between the worm and the wormgear for one turn of the table, as well as the value of backlash in the wormgear.

These measurements provide a sufficiently complete characteristic of the kinematic accuracy of the gear-cutting machine.

The main instruments used for checking consist of an autocollimator, a polyhedral mirror prism and a level.

The tube of an optimeter without the vibrating system can be used as an autocollimator, providing the scale of the tube is calibrated in angular units of 30-40" by means of a sine rule or an examiner.

A flat mirror 2 or a block gauge is attached to the sine rule 1 (Fig. 1). The tube of optimeter 3 is focused on to the mirror. Next, block gauge 4 is placed under the roller of the sine rule in order to displace the image of the scale with respect to the index sufficiently far in the field of vision of the eyepiece, for instance by ± 50 divisions. Then the value of the scale division in seconds is determined from the formula

$$n = \frac{\alpha}{k},$$

where α is the angle of rotation of the sine rule; k is the number of scale divisions corresponding to the elevation angle of the rule.

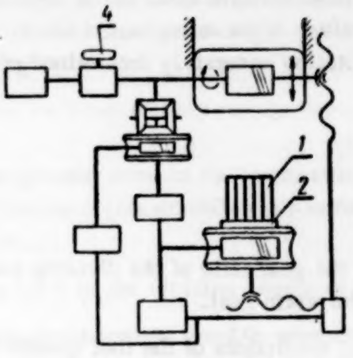

Fig. 2.

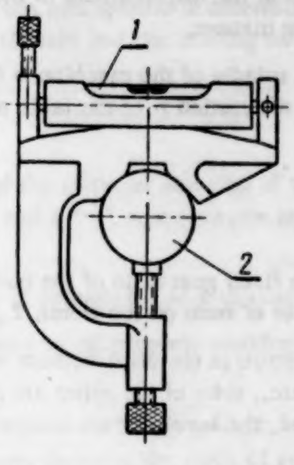

Fig. 3. 1) level; 2) spindle.

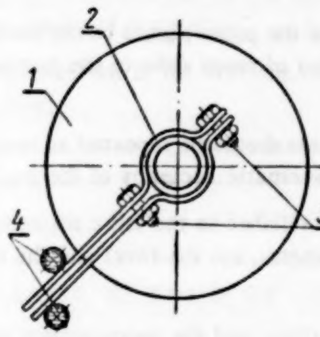

Fig. 4. 1) Table; 2) collar; 3) coupling bolts; 4) limiter.

When an examiner is used, a flat mirror or a block gauge is fixed to its calibrated disk and the optimeter tube is sighted so as to obtain in its eyepiece the image of the scale. Next, the calibrated disk is rotated until the scale is displaced with respect to the index by the largest possible number of divisions within the field of vision and the angle of rotation is noted at the same time.

The value of the optimeter scale division in seconds is then determined from the formula

$$n = \frac{m}{k}\, l\,,$$

where m is the number of divisions on the examiner disk; k is the number of the optimeter scale divisions corresponding to the disk rotation; l is the value of the examiner division in seconds.

The polyhedral mirror prism (metallic or glass) should have a maximum number of sides, which should be a multiple of the teeth in the worm gear (of the dividing gear). The central angles of the prism must be certified with an error not exceeding 3". The quality of the side surfaces must not be lower than grade 13.

The level calibrated in 20-30" should be certified with an accuracy of ±5". In the absence of a level a cam with an indicator can be used.

Figure 2 shows a schematic for checking the accuracy of the kinematic chain of burnishing-division of a gear-cutting machine.

A mirror 36-sided prism 1 is fixed to an adjustable table 2 of a vertical optimeter which is placed on the cone of the machine table; the optimeter tube 3 is fixed to an adjustable table of the type used in horizontal optimeters, and fixed by means of a bracket to the support of the machine. Level 4 is fixed to the stem of the tool spindle by means of a clamp in the manner shown on Fig. 3.

In order to find backlash in the kinematic chain of the machine it is recommended to use a brake similar to the device shown in Fig. 4.

Before starting the measurements it is necessary to set the machine for the required gear ratio $i_{\partial} = A/Z$, where A is the set ratio of the machine, Z is the number of sides on the prism. Next the position of the optimeter tube and the prism should be adjusted. The longitudinal and radial wobble of the mirror prism 1 should not exceed 0.010 mm.

The optimeter tube is fixed in such a position that its optical axis is perpendicular to the reflecting side of the prism and passes through the middle of the side both with respect to its width and height, and the zero graduation of the scale coincides with the stationary index.

The error in the displacement of the table for each complete rotation of the tool spindle is determined in the following manner.

The tool spindle of the machine is turned by hand through one rotation accurately determined on the level; then the angle of rotation γ of the table read off the scale will be

$$\gamma = \frac{360^\circ c_\partial k_w i_\partial}{Z_w k},$$

where c_∂ is the fixed gear ratio of the burnishing-division chain; i_∂ is the gear ratio of the dividing quadrant; k_w is the number of turns on the worm; Z_w is the number of teeth on the worm gear.

Next the errors in the displacement of the table for subsequent full revolutions of the tool spindle for the second, third, etc., sides of the prism are measured. Each time when a full revolution of the tool spindle is being completed, the level or cam is carefully approached to the zero position without allowing a reverse movement.

Should the zero position be exceeded measurement of this side of the prism should be omitted. Thus, the number of measurements for one turn of the table will equal the number of prism sides or the number of full revolutions of the tool spindle.

In order to obtain more reliable data, such cycles of measurements should be repeated at least 3 times. The measurement results should be entered into the test chart of the kinematic accuracy of the machine.

The error in the link between the worm and the worm gear is established in the same sequence from the first to the last side of the prism, with the same arrangement of instruments, but the level and the turning handle are fixed to the worm spindle on the quadrant side.

The technique of measurements is similar to the one described above and the measurement results are also entered on a chart.

A Chart for Checking the Kinematic Accuracy of a Gear-Cutting Vertical Machine (value of autocollimator calibration – 33.2")

Count No.	Number of prism sides	Calculated angle of the table rotation	Deviation of the prism angle according to its certificate	Readings on the optimeter tube: in scale divisions: first measment	second meas-ment	third meas-ment	Arithmetic mean in angular units	Error in the table displace-ment
1	1	0	0	0	0	0	0	0
2	1-2	10°	−12'47"	+21.5	+22	+22	+12'15"	−37"
3	1-3	20°	+0'07"	−1	−1	−0.8	−0'30"	−23"
–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–
36	1-36	350°	−8'02"	+13.5	+13	+13.5	+7'12"	−44"
37	1	360°	−0'06"	0	0	0	0	−06"

The measurement data are processed in the following manner.

Out of three or several scale readings the arithmetic mean σ is determined and expressed in angular units from the formula

$$\sigma'' = \frac{\sigma k}{60},$$

where k is the value of the scale division in seconds.

The error in the table displacement for one accurate rotation of the tool spindle is determined by the algebraic sum of the actual prism angle deviation $\Delta\alpha$ according to its certificate and the reading on the optimeter scale in angular units:

$$(\pm\Delta\alpha) + (\pm\sigma'').$$

The greatest error in the kinematic chain between the cutter and the table for one turn of the table is determined by the algebraic difference between the readings with a "+" and a "−" sign over one revolution of the tool spindle.

The error of the dividing couple of the worm and the worm gear is determined in a similar manner.

A more convenient graphic representation of the results is obtained by plotting the working cycle of the table's rotation.

For an efficient use of the equipment it is necessary to check periodically the kinematic accuracy of the machines during operation, and to test them out carefully after overhaul, dividing the stock of gear-cutting machines into grades of accuracy.

Any improvement in the dividing couple of the worm and the worm gear can only be attained by making a new worm gear.

A COLLIMATOR METHOD OF CHECKING BEARING RACEWAYS

Yu. V. Kolomiitsov, N. N. Panaiotova, and G. G. Smirnova

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 16-18, November, 1960

This autocollimation method provides highly accurate contactless measurements of the radius of curvature r in toroidal surfaces, including those of raceways in external and internal ball races (Fig. 1), and a qualitative evaluation of the shape of a raceway S arc.

The autocollimation method for measuring the radius of curvature in spherical surfaces, which is used in the optical industry for checking toroidal surfaces of ball races, is only possible if instead of the normal crosshairs a luminous spot is used in the collimator. When this spot is made to coincide with the center of curvature C of the raceway, the secondary image of the spot, which can be observed in the eye-piece field of vision, is drawn out into a narrow luminous line. The accuracy of adjustment to the center of curvature C is judged by the sharpness of definition of this line.

Figure 2 shows a schematic of the optical arrangement of an autocollimation equipment model checked under laboratory conditions.

Micro-objective 6 provides an image of the luminous hole 3 at its focus F. By displacing ball race 7 along the axis of the objective, the peak of the raceway's S arc and its center of curvature are made in turn to coincide with point F. In the first instance a sharply defined image of hole 3 is seen in the field of vision of eyepiece 9, and in the second instance a sharp narrow luminous line. The radius of curvature r of the raceway is equal to the displacement of the ball race read off a scale. For checking external ball races, special objective 6 is used with a rectangular prism which is placed inside the race.

It was found possible to measure on the model equipment radii of curvature of external ball races which had an internal diameter equal to or greater than 7 mm. It is, however, theoretically possible to check races

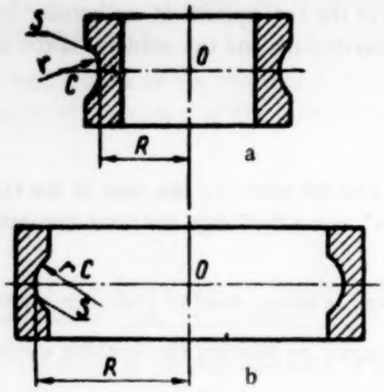

Fig. 1.

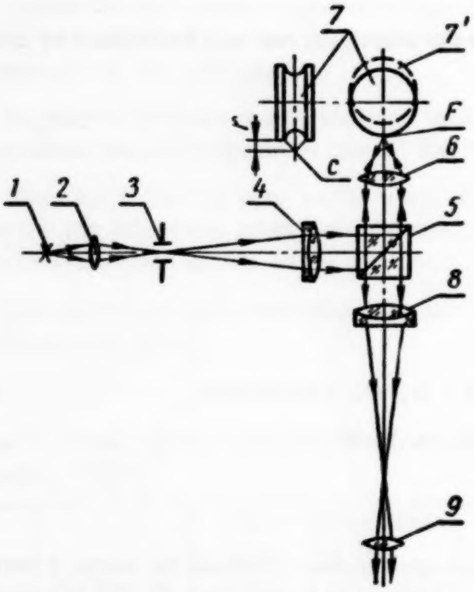

Fig. 2. 1) Incandescent lamp; 2) condenser lens; 3) diaphragm with a small round hole; 4) collimator objective; 5) tube with a semi-transparent diagonal; 6) micro-objective; 7) internal ball race under test; 8) telescope objective; 9)eyepiece.

of smaller diameters as well. The dimensions of internal races which can be measured are practically unlimited.

It is known that the basic error of the autocollimation method of measuring the radius of curvature consists of inaccuracies in focusing on the surface and on the center of curvature, and that the value of this error is inversely proportional to the square of aperture A of the micro-objective 6 in use. Calculations show that for an A = 0.3 it is possible to sight in either case with an error down to 0.8 μ, and for an A = 0.6 with an error down to 0.2 μ. In practice the error of sighting on the center of curvature of the raceway S arc (Fig. 1) is larger, since this arc normally has considerable deviations from an ideal circumference, thus leading to a blurring of the luminous line image.

The narrowest image of the line is obtained when the raceway's center of curvature coincides with the micro-objective focus.

Below we give the results of measuring by means of a micro-objective with an A = 0.4 of the radii of curvature of two relatively good internal ball races with a nominal value of $r = 1.05^{+0.03}$ mm. Different experimenters carried out 4 series of measurements of raceway radii $\underline{r}$ in ball races Nos. 1 and 2, with 10 measurements in each series. Mean values of each series of measurements and the corresponding values of the quadratic mean error are given in the table.

Ball races of a lower quality than Nos. 1 and 2 provide blurred images of the luminous line, thus making the "zero" position of the race for which the image of the line is most sharp rather indefinite, and increasing the error in measuring $\underline{r}$.

Photographs of the luminous lines in four ball races of the same type, which were set in the zero position with the greatest possible accuracy, were obtained and compared. Ball race No. 1 provided a narrow line with sharply defined edges. A somewhat wider but uniformly illuminated line was obtained from ball race No. 2. The width of the line for ball race No. 3 is considerably larger and its illumination unequal; several bright lines are superposed over a dimly lighted background and each of them narrows down for different positions of the ball race. The splitting of the luminous line shows the existence on the raceway S arc of sections corresponding to circles with different centers of curvature. Ball race No. 4 provides such a blurred image that the measurement of the radius of curvature becomes impossible.

Experiments have shown that the definition of the luminous line does not depend upon the quality of surface finish of the raceway, providing it is not lower than grade 11-12.* Thus, when the above-mentioned ball races were tested on microinterferometer MII-4 it was found that ball races Nos. 2, 3 and 4 have roughly the same grade of surface finish (grade 12-13), whereas ball race No. 1, which produced the most sharply defined

* For a rougher surface finish (for instance after grinding) the surface of the raceway does not reflect like a mirror the rays incident to it thus making it impossible to use the autocollimation method.

Ball race No. 1		Ball race No. 2	
r, mm	σ, μ	r, mm	σ, μ
1.038	2.0	1.039	1.4
1.036	1.2	1.041	2.1
1.038	1.3	1.036	1.8
1.040	1.9	1.037	2.4

line, had a surface finish of a lower grade, namely 11-12. This indicates that the blurring of the line is caused by deviations of the raceway S arc from a true circle or by a waviness of the raceway surface in the S cross section. This assumption is confirmed experimentally, since the width of a blurred luminous line can be considerably reduced by covering up part of the light beam incident to the ball race, and thus cutting out reflections from a part of the raceway S arc sections.

Thus the autocollimation method is a very sensitive means of discovering local deviations of the raceway arc from a regular circumference. Small deviations provide a narrow image of the luminous line and a more accurate measurement of the raceway radius of curvature $\underline{r}$. The reduced accuracy in measuring $\underline{r}$ when the shape of the surface becomes distorted is to be expected since the very conception of a center and radius of curvature of an arc becomes indeterminate if this arc has an irregular shape or consists of several small arcs with different centers of curvature.

The testing of a large number of internal and external ball races showed that in the majority of cases it is advisable to use for measuring $\underline{r}$ micro-objective 6 (Fig. 2) with an aperture of $A > 0.40$. A large A leads on the one hand to an increase in the length of the raceway arc tested at a time and a consequent deterioration in the sharpness of the luminous line. Yet on the other hand, for an efficient evaluation of an S arc shape it is desirable to use an objective with an aperture large enough to make the incident ray cover as large an area of the controlled surface as possible. Calculations show that for an $A = 0.75$ the ball race arc of the majority of bearings produced by our industry is completely covered.

The minimum width of a luminous line obtained for given values of aperture and micro-objective magnification can serve as a criterion for a quantitative evaluation of the correct shape or waviness of the raceway arc. For sorting ball races it is possible to fix in the field of vision of the eyepiece two hairlines parallel to the image of the luminous line and placed at a distance of the required tolerance from each other.

It is also possible to measure by means of the autocollimation method the end wobble of ball races. For this purpose it is necessary to measure the transverse displacement of the luminous line while the ball race is being rotated by means of an eyepiece micrometer. If the full magnification of the instrument's optical system is used, it is possible to measure wobble with an error of the order of 1 μ.

ATTACHMENT FOR A VERTICAL OPTIMETER

N. K. Ochinskii

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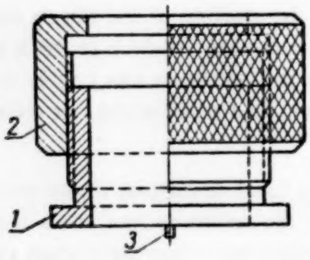
November, 1960

When checking block-gauges with nominal value of 2 to 10 mm it is necessary to lift the tube of a vertical optimeter by 0.5 mm at least 16 times.



Since the projection attachment has come into use the weight of the lifted part has risen to over 3 kg, which makes it difficult to lift it manually for short distances.

In order to make this lifting easier the Zaporozh'e State Inspection Laboratory has developed and produced a special device (see figure), which consists of a bush 1 and a thumb-nut 2, with a 1 mm pitch thread. The bush together with the nut is placed over the optimeter tube; then the tube is fixed in the bracket in such a way that its pin engages with the groove in the bracket, thus preventing the rotation of bush 1 with respect to the bracket. So that the pin should not hinder the fixing of the tube in the bracket, the diameter of the pin should be smaller than the groove in the bracket in its fixed position; if necessary the bracket groove should be made wider for a height equal to that of the pin. The raising and lowering of the optimeter tube is then attained by turning nut 2 with the bracket fixing screw released.

The tube is set accurately to "zero" by means of the table-lifting microscrew.

A DEVICE FOR CHECKING REFERENCE GAUGES FOR MICROMETERS WITH INSERTION PIECES

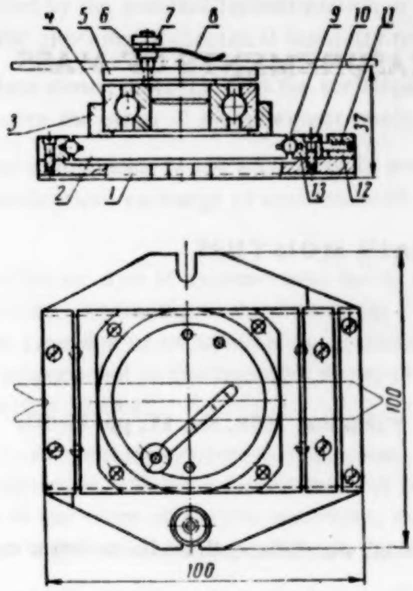
I. A. Razumovskii

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, p. 19,
November, 1960

The Central Test Laboratory of the Ordzhonikidze Plant has developed and produced a device for checking reference gauges for micrometers with insertion pieces by means of measuring machines or horizontal optimeters.

The device consists of an additional table superposed on the table of the machine or optimeter. This additional table has two free movements: a rotary motion about a vertical axis, and a forward motion in the transverse direction. These two motions make the reference gauge "self-adjustable" when it is placed between the inserts.

The construction of the table is shown in the figure attached: plate 1 carries by means of screws 10 two strips 13 with knife-edge grooves and one strip 12, which serves to adjust strip 13 by means of two screws 11; the plate has two grooves by means of which and bolts with nuts the whole table is fixed to the table of the measuring machine or the horizontal optimeter.



On table 2, which moves on four balls 9, ring 3 is fixed by means of four screws.

Grade C bearing 4 is pressed into ring 3 and carries a pressed-in round table 5, to which the reference gauge is secured by means of bolts 6, nuts 7 and springs 8.

The reference gauges are measured by means of the above equipment in a manner specified in instruction 125-57.

Moreover, the reference measure is placed on the table in such a manner that its axis of rotation in the horizontal plane is as close as possible to the tapered insert fixed to the optimeter tube. This will provide a minimum or maximum reading on the optimeter scale depending on the shape of the gauge angle inserted in the prismatic cap–whether it is conical or limited by the planes of a bilateral angle.

This device is simple in construction and can be made at any plant.

MEASUREMENTS OF MASS

ACCURACY IN MEASURING GRAIN MOISTURE BY THE DRYING METHOD*

V. I. Loshak

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 20-23, November, 1960

The variation in the mass of grain ΔM, which depends on its moisture content**, is determined from the formula

$$\Delta M = M_1 \left(\frac{W_1 - W_2}{100 - W_2} \right), \tag{1}$$

where W_1 and W_2 are respectively the initial and final moisture in the mass of grain.

An analysis of (1) shows that in order to maintain the accuracy of recording corresponding to the accuracy in measuring the difference of mass by the weighing method, it is necessary to measure humidity with an error not exceeding ± 0.2%. Similar accuracy for measuring humidity is required when storing grain for long periods or checking the condition of grain stocks.

GOST (State Standard) 3040-55 entitled "Grain and the Methods of Determining its Quality" lays down in paragraph D that the basic method for determining the humidity of grain consists in drying weighed portions of ground grain in an electric drying oven type SÉSh-1.

A 30 g sample of the tested grain is ground in a laboratory mill, sifted and carefully mixed. If the humidity of the grain is over 18% the grain is dried before grinding at a temperature of 105°C during 30 min. The preliminary drying is necessary because grain with a humidity exceeding 18% cannot be ground; it is squashed and clogs up the mill. After preliminary drying the sample is again weighed before grinding. Next, two 5 g portions of the ground grain are measured out. Boxes with weighed portions are placed in a drying chamber and dried with open lids at a temperature of 130°C during 55 min. The boxes are placed in the chamber when the temperature of the latter has reached 140°C. After drying the boxes are closed, placed in an exsiccator, cooled to room temperature and then weighed. The humidity of the sample is determined by the loss of mass with reference to the original weighing.

All the weighing is done on commercial balances with a tolerance of ± 10 mg.

The basic criterion for determining the accuracy of these measurements according to the GOST consists in the value of the deviation between two measurements made on the same samples. Numerical values of the permissible deviation have been established by the GOST for two cases. The first case consists of measurements made in the same cabinet, and the tolerance amounts to 0.25% humidity (the so-called deviation between parallel measurements). This tolerance determines the requirements with respect to the apparatus and the technique of measurements of the basic method, which provide an agreement of the results with the above accuracy. The second case is for measurements made in different cabinets, and even different laboratories, which occurs in inspection and umpire testing. According to the standard the second tolerance should not exceed 0.5% humidity.

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* As a contribution to the discussion.

** For the sake of brevity, "moisture content" will hereafter be referred to as "humidity" [Publisher's note].

The same tolerance is provided by the standard for comparison of other methods with the standard method of measurements, which includes the checking of electrical humidity meters.

The existing experimental data shows, however, that the technique outlined by the GOST does not ensure the required tolerances and in practice the errors of measurement attain larger values than those specified.

Let us examine separately the components of the total error in measuring humidity which are due to the following factors: the method of dessication, exchange of moisture with the ambient atmosphere, the apparatus used and errors in weighing.

The dessication method provides an error of measurement due to the use of a single or double-stage method of drying for various limits of humidity. According to the data of the VNIIZ (All-Union Scientific Research Institute of Grain) (S. S. Suvorov) the error due to an incomplete extraction of moisture in single-stage as compared with double-stage drying is proportional to the humidity of the sample and amounts to 0.05% for a humidity of 11% and to 0.50% for a humidity of 18%.

In addition to the error due to incomplete extraction of moisture, the use of two different dessication methods, which produce such pronounced differences, creates a discontinuity in the measurement result of 18% humidity, making all the values of humidity in the range of 17-19% uncertain, since for one and the same sample it is possible to obtain values smaller or larger than 18% depending on the dessication method used.

Moreover, according to the existing technique it is not known whether single or double drying should be used until the sample has actually been tested.

Neither is it possible to make the two methods agree by extending the dessication time, since this produces an error due to oxidation which increases the weight of the sample.

The simplest solution of this question consists in adopting the two-stage drying method over the whole range of humidity starting with 12-13%. This would create a uniform measuring technique, reduce the error due to loss of moisture during grinding of undried samples, eliminate the difference in the humidity values in the range of 18%, and make the humidity measurement uniform over the whole testing range.

Exchange of moisture with the atmosphere. The extent to which moisture is extracted during air drying depends to a considerable degree on the humidity of the atmospheric air. According to the data of the VNIIZ a variation in the moisture content of air from 2 to 20 g/kg produces a variation in the extracted moisture from 0.9 to 1.0%. For normal variations in the humidity of air this quantity amounts to 0.4-0.5%.

Such a marked effect of the humidity of the ambient medium on dessication is the main defect of the air-drying method, which makes it impossible to obtain consistent results for the same sample in different places or at different times. This effect can be eliminated only by the repeated measurements under conditions of unchanged air humidity. In practice this can only be achieved, however, if measurements are made in the same place at intervals during which there are no marked changes in the conditions of the weather. It is obviously impossible to place such limitations on this technique, since this would preclude its utilization for checking and umpire testings.

It is generally accepted that the grinding of grain, necessary for humidity determination, produces a marked loss of moisture to the surrounding medium. The value of this loss according to different investigators amounts to 0.1 to 0.5%, depending on the humidity of the grain being ground. It is also thought that this is the main source of errors in the air-drying method. This is not correct. The tests we made of the variation in the mass of measured-out grain during its grinding in boxes with the grinding equipment built into them (and without removing the grain out of the boxes) showed that the loss of moisture mainly occurs after grinding, when the grain comes into contact with air after its removal and during its weighing (see table).

It was also established during these tests that if the grain is ground after a preliminary drying to a humidity of 8%, i.e., to a value below the humidity equilibrium, there occurs instead of a loss an absorption of moisture from the air to the amount of 0.04 to 0.06%.

It should be noted that preliminary drying of unground grain produces residual humidity of 8-10% irrespective of the initial humidity of the grain. Thus, by introducing compulsory preliminary drying it will be possible to establish identical conditions for grinding and obtain the same degree of fineness in grinding

Humidity of the ground grain, %	12	15	18	Grinding fine enough to pass 100% through a sieve with 1 mm holes
Loss of moisture during grinding, %	0.06	0.1	0.15	
Loss of moisture during 5 min after grinding, %	0.1	0.17	0.3	

irrespective of the humidity of the initial sample. It will also be possible to reduce the loss of moisture during grinding and separation of weighed samples, since there will now be a humidity equilibrium with the surrounding air.

The apparatus used produces measuring errors due to difference in the drying conditions. Here we should consider the effect of drying in the same or different cabinets.

The differences in drying conditions when several weighed portions are dessicated in the same cabinet only depend on the uneven temperature field inside the cabinet, which produces different drying temperatures for the boxes containing grain and placed in different compartments of the cabinet.

For the type SÉSh-1 cabinet this difference amounts to 2-3°C, resulting in a difference of humidity measurements of 0.1-0.15%. It should be noted that in the new model SÉSh-3 cabinet a more uniform temperature field has been attained by rotating the table with the samples and a forced flow of air round the grain boxes produced by a ventilator.

In the case of consecutive measurements in the same cabinet differences arise owing to inaccuracies in setting the drying temperature and errors in estimating the duration of drying.

Appreciable inaccuracy in repeating drying temperatures may arise if contact thermometers with a magnetic head which displaces the contact needle are used. In these thermometers the error in reproducing temperatures may attain ± 0.5°C with a scale of 0-150°C and graduations of 2°C. For contact thermometers with permanent contacts this error is small.

An error as large as 1 min in a total exposure to drying of 1 hr does not produce a noticeable effect on the measuring results.

Thus, the reproducibility of consecutive measurements in the same cabinet is characterized by the same value as the reproducibility of simultaneous measurements, providing the consecutive measurements are made at a constant temperature and humidity of the surrounding air.

The reproducibility of measurements made in two cabinets placed in the same or different laboratories depends not only on variations in the extent of dessication due to differences in the humidity of the surrounding air, but also on differences in the actual drying temperature produced by the inaccuracy in setting contact thermometers, and variations in the fineness of grinding when the weighed samples of grain are prepared.

In the SÉSh-1 type cabinet the drying temperature is measured with a thermometer whose bulb is placed over the grain boxes in the rising stream of air which flows between the boxes. Measurements of the temperature of the drying objects which we made by means of thermocouples inside the boxes showed that the actual temperature of the objects in the boxes was 10-12°C higher than the reading of the thermometer placed over the boxes. Since the position of the thermometer bulb is not specified by the standard, humidity measurements will depend on the distance between the bulb and the boxes. It was established experimentally that variations in the position of the bulb along a vertical line from the bottom of the box to a level 25 mm above the lid of the box changes the humidity level obtained by dessication by 0.1-0.2% (the larger error refers to humidities of 16-18%). It is obvious that for standard equipment the position of the thermometer bulb should be strictly specified, and equipment produced in which the bulb is fixed in a definite position with respect to the boxes.

A considerable effect on the error in reproducing drying conditions is exerted by the errors in the thermometer itself. The contact thermometers at present used in the SÉSh-1 cabinets have a magnetic head type TK-6, a scale of 0° to 150°C calibrated in 2°C. The choice of these thermometers cannot be considered satisfactory. The rough calibration makes an accurate setting of the contact needle to the required temperature difficult, and

since the transition from preliminary drying to final dessication requires a resetting of the needle, this circumstance, together with the possible deviations in the reading of the thermometer itself equal to ± 2°C, introduces an error in the reproducibility of conditions which may produce an additional deviation in the measured humidity of 0.1%.

Error of weighing. Let us express humidity W by means of consecutive measurements of the box B with humid B_h and dried B_d weighed portions of grain:

$$W = \frac{B_h - B_d}{B_h - B} 100\%, \tag{2}$$

where B_h is the weight of the box with the weighed humid portion of grain; B_d is the weight of the box with a weighed dried portion of grain; B is the weight of an empty box.

The quadratic mean error for three independent weighings, which are assumed to be of equal accuracy, is

$$\sigma_W = \sigma_B \sqrt{\left(\frac{\partial W}{\partial B_h}\right)^2 + \left(\frac{\partial W}{\partial B_d}\right)^2 + \left(\frac{\partial W}{\partial B}\right)^2}, \tag{3}$$

where σ_B is the error of a single weighing.

From (2) and (3) we obtain

$$\sigma_W = 100\sigma_B \frac{\sqrt{(B_d - B)^2 + (B_h - B)^2 + (B_h - B_d)^2}}{(B_h - B)^2}. \tag{4}$$

Denoting the mass of the weighed portion by $D = B_h - B$ and the loss of mass in drying by $A = B_h - B_d$, we obtain the final formula for calculating the error in humidity measurement due to weighing:

$$\sigma_W = 100\sigma_B \frac{\sqrt{2(A^2 + D^2 - AD)}}{D^2}. \tag{5}$$

Since A = 0.01 WD, where W is the percentage moisture content in a weighed portion, expression (4) can be finally represented in the form

$$\sigma_W = 100\sigma_h \frac{\sqrt{2\left[\left(\frac{W}{100}\right)^2 - \frac{W}{100} + 1\right]}}{D}, \tag{6}$$

from which it will be seen that the error due to weighing is inversely proportional to the size of the weighed portion and is hardly affected by the loss of the mass in drying.

For the mass D = 5 g of a weighed portion specified by GOST 3040-55, and the tolerance in single weighings of $\sigma_B = 0.01$ g, the error in the humidity measurements due to weighing, calculated from the above formula, amounts to 0.26-0.28% irrespective of the initial humidity of the grain.

Thus, the tolerance in weighing specified by the GOST 3040-55 does not preclude the possibility of an error in humidity measurements which is larger than the permissible deviation between parallel determinations of humidity.

It should also be noted that the weighing of a box with grain of a total weight of 20-30 g with an error of ± 10 mg, specified by the standard, can only be provided if 1st grade commercial balances are used.

If 100 g 2nd grade commercial balances with an error of ± 20 mg at the maximum load are used, cases may arise when the error of weighing will be twice as large as the tolerance specified for humidity measurements by the basic method.

In order to insure the required accuracy of measurement it is necessary to supply all the laboratories with 1st grade commercial balances, whose production must be organized at the "Gosmetr" Plant, or to adopt analytical balances for these measurements, thus reducing considerably the error of weighing with respect to the one specified by the GOST.

SUMMARY

The defects in measuring the humidity of grain by the methods specified by GOST 3040-55 produce errors which lower the reproducibility and accuracy of measurements with respect to tolerances specified by the same standard.

In order to raise the accuracy of measurement it is necessary to introduce in the methods specified by the GOST 3040-55 the following amendments:

To measure humidity by the two-stage method in all the cases when it exceeds 12-13%, i.e., practically in all the normally encountered cases. This will provide an identical fineness of grinding and a better reproducibility of consecutive measurements. It will no longer be necessary to make preliminary tests of a sample for determining whether a single or two-stage method of drying should be used, and a uniformity will be established both in the technique of measuring humidity and in the results obtained over the whole range of testing.

Instead of specifying cabinet SÉSh-1 as a standard, a specification should be issued for the method of drying and the design requirements ensuring a uniform temperature field within given tolerances (differences between the heating temperature of boxes placed in various compartments of the cabinet) and an accurate and constant temperature during drying. Thus it will be possible to produce new designs of cabinets without altering the standard.

The standard must indicate the exact position of the thermometer bulb, and specify that the thermometer reading should correspond to the temperature of the product inside the boxes and not that of the air surrounding the boxes.

The weighing out of portions and determining the loss in the mass should be made with an error not exceeding 4 mg which is specified for 1st grade commercial balances.

The preliminary drying of unground grain should be made in a cabinet with forced ventilation and in boxes made of wire netting. This will reduce the duration of drying from 30 to 8-10 min and speed up the cooling of samples which is required before their weighing.

In order to simplify the determination of the quality of grinding it is advisable to establish for all grain crops (except oats) that the ground grain should be fine enough for 100% of it to pass through a sieve with 1 mm holes.

The above measures provide a considerable increase in the accuracy and reproducibility of measurements, thus ensuring for the basic method the tolerances specified by the standard.

The only error which has not been eliminated is the one due to the degree of humidity of ambient air. This error is inherent in air drying and can only be eliminated by adopting vacuum drying, which will also eliminate the error due to the oxidation of the dessicated product when it comes into contact with heated air.

Drying in vacuum is at present the most promising form of dessication for establishing a reference method of measuring the humidity of grain.

THE EFFECT OF THE TEMPERATURE OF THE WEIGHED BODY ON THE WEIGHING RESULTS

P. V. Rudenko

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 23-24,
November, 1960

In several state standards a weighing method of determining moistness has been adopted, according to which the moisture content of a product is determined by the equation

$$W = \frac{P - P_1}{P} 100,$$

where W is moistness of the product, %; P is the mass of the weighed portion before drying; P_1 is the mass of the weighed portion after drying.

Moreover, the temperature of the sample during weighing before drying is usually equal to that of the premises, but its temperature after drying is considerably higher than that of the ambient medium, since the sample doesn't get enough time to cool.

This circumstance leads to a considerable error in the experiment due to two causes:

a) a warm sample has a larger volume and, hence, when it is weighed in air it loses in its weight, according to the law of Archimedes, more than a cold sample;

b) the warm sample produces vertical convection air currents, which tend to drag behind them the scale pan, thus producing an apparent reduction in the mass of the sample.

The first error is well known and can be eliminated if the equation given below is used for determining moistness:

$$W = \left(\frac{P - P_1}{P} + \frac{v_t - v}{v}\, e\right) \cdot 100,$$

where v_t is the volume of the heated sample; v is the volume of the cold sample; e is the density of air.

In the majority of cases this error is small and can be neglected.

The second error is larger and cannot be neglected. Thus, in determining the moistness, for instance, of wool by means of the moisture-measuring apparatus type VKA-2, in which the dried sample is weighed without taking it out of the drying chamber, this error amounts to 0.6-1.0%.

Thus, in all standards which use a weighing method for determining moistness, it is necessary to note that the weighing of the dried sample should be made at the same temperature as the weighing of the sample before drying, or a correction factor should be used, which will differ for each particular case depending on the size of the sample, the heating temperature, and the size and material of the container in which the sample is placed.

MEASUREMENTS OF TIME

PROGRESS IN MEASUREMENTS OF TIME AND THE ESTABLISHMENT OF NEW METHODS FOR MEASURING PHYSICAL QUANTITIES

A. I. Gordienko and A. A. Korotkov

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 24-26, November, 1960

Owing to the rapid development of electronics it is now possible to determine the unit of time, the second, and its fractional values with an error not exceeding 10^{-8} [1]. According to this characteristic measurements of time will soon attain a level similar to that of the measurements of length [2, 3].

However, this is far from being the limit, since an atomic clock has already been made which has a considerably smaller relative instability, but even its characteristic will be improved, since the instability of internal atomic oscillations is of the order of 10^{-16}.

The problems of the reliability and life of the apparatus intended for keeping the measure of time will also be solved in the near future.

Side by side with the development of reference measures of time, chronometric measuring instruments and generators of small time intervals are being successfully assimilated in research and production control.

A considerable improvement in the accuracy of chronometers was attained by using standard frequency generators and counting circuits, which make it possible to compare time intervals with a whole number of periods of reference oscillators. The error of the so-called time counters amounts to $5 \cdot 10^{-7}$.

Counting circuits are successfully used not only for measurements, but also for calibrating small time intervals with an error of 10^{-4} sec and a relative error of 10^{-2}% [5], as well as with an error of 10^{-5} sec and a relative error of $3 \cdot 10^{-3}$% [6]. The top limit of the measured and calibrated time intervals can be very large.

The prospects of developing the accuracy of these instruments are also unlimited, since time counters can use a converted reference frequency for counting and comparison.

The conversion of a set of frequencies (for instance, a decade frequency scale) will provide greater possibilities for selecting time pulses which determine standard intervals of time of different durations.

The greater sensitivity in timers was obtained by means of capacitance methods of measuring small time intervals. Thus, as early as 1947 our industry produced its first timers calibrated in 10^{-7} sec [7]; information is available on timers measuring by means of the capacitor method intervals of the order of millimicroseconds [8].

A combination of capacitor timers with their high sensitivity, and counting timers or convertible time signals with their high accuracy, provides further possibilities in the development of the counting technique.

Our industry is supplied with a full set of timing equipment which covers a wide range of measurements and calibrations, from commercial instruments and transducers with an error of 5% to precision apparatus with errors of a few thousandths of a percent.

This circumstance, as well as the prospective development of timing equipment, raises the problem of reviewing the existing and of developing new methods of measuring many not only electrical, but other physical quantities by means of measurements of time.

The new methods will not only extend the measuring facilities and production control, and raise their accuracy, but will provide the basis for a wide automation of checking and control operations, since time counters are simple to maintain, sufficiently reliable in operation and can be applied for controlling technological processes related to time.

Thus, a new method of measuring capacitance was successfully used in measuring components of a complementary circuit for simulating a dc capacitor with an imperfect dielectric [9]. The method of using frequency for measuring and calibrating time intervals has led to an advanced method of measuring an unknown frequency by means of a pulse-counter and a generator of a reference time interval (a second or fractions of a second); this method provides the possibility of measuring frequency under production conditions with an error of $5 \cdot 10^{-5}$ [10] and even $5 \cdot 10^{-7}$ [4].

The extension of the range of measured quantities is only possible if these quantities are related to time or its derivatives. For instance, if charging (discharging) electrical circuits are used, such quantities can include voltage, current, resistance, capacitance, power, energy, etc., or such mechanical quantities as length, speed, acceleration, momentum, power, etc. [11].

The measurement of physical quantities can be divided into two groups with respect to the nature of the relationship between the physical quantity and time. The first group includes measurements which are directly proportional to time, such as the period of electrical and mechanical oscillating systems, time constants of RC and LR electrical systems; the second group includes measurements inversely proportional to time, such as resistance, quantity of magnetism, magnetic flux, current, etc., in electrical systems, and speed, angular velocity, momentum, internal friction, thermal conductivity, etc., in mechanical systems. Taking into consideration the inverse proportionality between time and frequency, the variables of the second group can be measured more conveniently by means of frequency in a similar manner to those of the first group.

The methods used for such measurements are already known [10].

For each group of measurements determined by the sign and the value of the time dimension index it is necessary to have a corresponding scale on the timer (linear, logarithmic, hyperbolic, etc.), and in addition for all the groups corresponding "coefficient" generators which should represent the relation of the measured quantity to other quantities in the form of a coefficient. Thus, when measuring voltage V for a linear charging of capacitor C and a known value of direct current I according to formula

$$V = \frac{I}{C} t = At,$$

the measure of time $\underline{t}$ must have a linear scale, and coefficient A must be provided by the coefficient generator, which should contain in addition to capacitor C a source of stabilized current, whose value should not change during the charging of the capacitor.

Similar coefficient generators are required when the variable is measured by means of a frequency. Thus, on the basis of the above formula the current can be represented by equation

$$I = \frac{CV}{t} = Nf,$$

where the measure of frequency f must also have a linear scale, and coefficient N must be produced by the coefficient generator which should contain a relaxation oscillator for charging capacitor C up to the set voltage V.

It is more difficult to measure variables which are related to time (or frequency) by a quadratic or more complex law. However, even in such a case great possibilities exist of producing suitable timers, owing to the flexibility of electronic circuits [12].

It is possible that the application of similar methods for measuring derived electrical and other quantities (for instance, acceleration due to gravity) will produce favorable results, similar to those obtained for measuring electrical resistance in terms of frequency by the Lorenz method [13].

SUMMARY

1. The progress made in time measurements, which are characterized by relative ease in obtaining high accuracy and resolution, a wide range of measurements with a relatively simple measuring procedure, and the possibility of high-speed measurements, provides the necessary prerequisites for measuring various quantities related to time by means of counting and capacitor timers, which are already widely used in industry. The prospects of this method are particularly encouraging if one considers the vigorous development of the computer technique.

2. Measurements in terms of time are being successfully applied in many instances; finding new spheres of application for this method is the task of the near future.

3. New methods of measuring various quantities related to time in terms of time and frequency not only widen the potentialities of measurements and production control but also those of automation in control operations.

LITERATURE CITED

1. Fischer and Marshal, Proc. Nat. Electronics Conf. (February, 1954).
2. M. F. Romanova, Adopting a Light Wavelength for Determining the Unit of Length, Trudy VNIIM 7 (67) (1949).
3. Metrology, Standards and Precision Measurements [in Russian] (issued by the Committee of Standards, Measures and Measuring Instruments attached to the Council of Ministers, USSR, 1957).
4. Count Meter for Measuring Frequency and Time Intervals [Russian translation] (FELZB No. 4735 of the firm of "Rode and Schwarz," Bulletin from the series "Foreign Technology," 1, 1958).
5. A. D. Veisbrut, Izmeritel'naya Tekhnika No. 6 (1957).
6. A. A. Iogansen, Calibrating Stopwatch Type 800. Advanced Scientific, Technical and Production Experience, subject 31, No. P-58-34/6, 1958.
7. A. M. Ul'yanishchev, Electronic Millisecondmeter 506-A and Microsecondmeter Type 576, Instruments and Racks, Subject 1, No. I-56-405.
8. I. Lewis and F. Wells, Millimicrosecond Pulse Technique [Russian translation] (Foreign Literature Press, 1956).
9. A. I. Gordienko and G. I. Chirkov, "New Method of Measuring Capacitance and the Results of Evaluating a Complementary Circuit of dc Capacitors," collection: Investigating the Stability of Paper Capacitors [in Russian] (Oborongiz, 1, 1956).
10. Electrical Engineering (June, 1956).
11. L. R. Neiman and P. L. Kalantarov, Theoretical Foundations of Electrical Technology [in Russian] (part 1, Gosénergoizdat, 1948).
12. Generation of Electrical Oscillations of a Special Shape [in Russian] ("Sovetskoe Radio" Press, 1951).
13. S. F. Malikov, Practical Electrical Units [in Russian] (Gosénergoizdat, 1947).

MECHANICAL MEASUREMENTS

REFERENCE 1st GRADE LEVER-TYPE DYNAMOMETER

I. S. Gorpinchenko

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 26-28,
November, 1960

For evaluating the errors and consistency in transmitting a force from a 2nd grade reference stationary equipment by means of a 3rd grade reference dynamometer we carried out the following tests: three 3rd grade reference dynamometers, which were previously carefully tested on a 2nd grade installation at the VNIIM (All-Union Scientific Research Institute of Metrology) for their consistency, were calibrated on stationary 2nd grade equipment in Moscow, Sverdlovsk and Novosibirsk. The calibration data obtained for the same dynamometer on various instruments differed from each other by up to 2%, and the quadratic mean errors of the dynamometer calibration data obtained on various instruments exceed tens of times the error obtained by the VNIIM. These measurements once again confirmed the pressing necessity of producing 1st grade dynamometers.

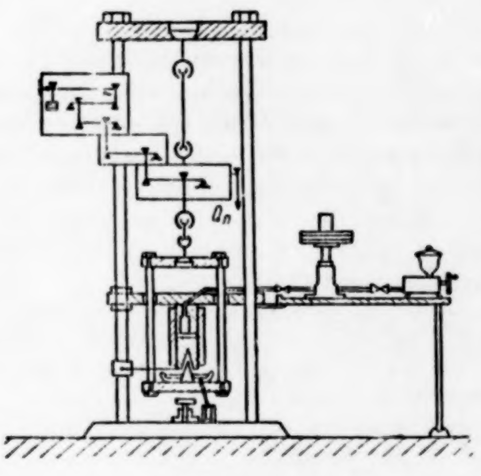

Fig. 1.

The unequal arm lever systems [1] studied by us made it possible to design portable equipment with a gear ratio of the order of 25,000 and a limiting measuring error not exceeding ± 0.05% of the measured value.

The kinematic chain of the proposed lever-type dynamometer consists of a combination of unequal arm levers of the first and second order with total gear ratio 25,000. The set of the first three levers, mounted in a separate box, has a nominal gear ratio of 500 with measuring limits of 100 to 1,000 kg-wt; a set of four levers has a nominal gear ratio of 2,500 with a range of 500 to 5,000 kg-wt; the aggregate of all the seven levers makes up a portable instrument of a lever type with a nominal gear ratio of 25,000 and a range of 1,000 to 50,000 kg-wt.

Repeated tests of these instruments consisted in evaluating the error of the dynamometer by loading it directly with reference weights.

The data thus obtained showed that the limiting relative error of the lever system with a gear ratio of 500 did not exceed 0.003% at its top limit (1,000 kg-wt), i.e., it was possible to determine a weight of 1,000 kg with a limiting error of ± 30 g, and a weight of 5,000 kg with a limiting error of ± 500 g.

This error of the lever systems under investigation makes it possible to assert that they can be successfully used for measuring weights from 100 to 5,000 kg and even higher with an accuracy satisfactory for metrological purposes.

Since the above instruments are of a portable type, additional tests were made in order to discover the effect of their dismantling, reassembly and adjustment on the value of the error.

Dynamometer	Measurement limit P kg-wt	No. of complete adjustments m	Total No. of measurements n	Evaluation of the general dispersion S_1^2	Dispersion between sets of adjustments S_2^2	Evaluation of the dispersion caused by adjustments, ω^2	Evaluation of the total quadratic mean error $\sigma_{ij} = \frac{\sqrt{\omega^2+S_1^2}}{i}$
Three-lever i = 500	100	5	30	0.00070	0.0487	0.0080	0.0180
	200	5	30	0.00050	0.0560	0.0964	0.0198
	300	5	30	0.00090	0.0180	0.0029	0.0108
	400	5	30	0.00040	0.0650	0.0107	0.0207
	500	5	30	0.00070	0.0350	0 0057	0.0151
	600	5	30	0.00060	0.0028	0.0004	0.0040
	700	5	30	0.00008	0.0190	0.00312	0.0112
	800	5	30	0.00013	0.0000	0.00132	0.0073
	900	5	30	0.00016	0.0580	0.00964	0.0198
	1000	4	24	0.00016	0.0130	0.00214	0.0096
Four-lever i = 2,500	500	3	30	0.0705	0.650	0.058	0.014
	1000	5	30	0.2030	2.650	0.244	0.027
	2000	2	20	0.0080	1.099	0.109	0.013
	3000	2	20	0.0160	0.138	0.012	0.007
	5000	4	38	0.1680	0.704	–	0.019

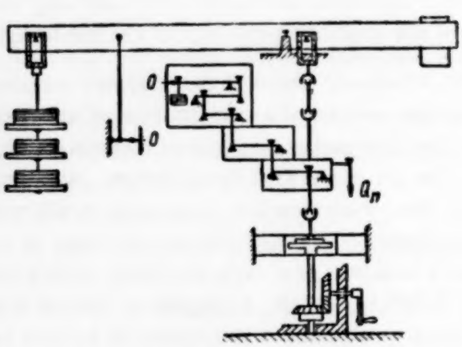

Fig. 2.

The instruments were repeatedly dismantled, reassembled and transported and after readjustment used for a series of measurements of various loads [2]. By means of these measurements we determined the quadratic mean error of the lever system's gear ratio due both to the measuring procedure and to the reassembly and adjustment of the instruments. The data thus obtained were subjected to a dispersional analysis.

The total quadratic mean error due both to the measurement procedure and the adjustment of the instrument is determined by the formula

$$\sigma_{ij} = \sqrt{\omega^2 + S_1^2}\ .$$

The values of σ_{ij} for the corresponding loads are shown in the table.

The data given in the table show that it is impossible to ignore the effect of assembling and adjusting (a new instrument), since the value of ω^2 is of the same order as that of S_1^2. The last column shows the quadratic mean deviations which depend both on the measurement errors and the errors of adjustment.

The tests carried out on the multilever portable instruments lead to the following conclusions: the dismantling, reassembly and adjustment of the instrument introduce into the total error an additional component which must be taken into account, and whose value is of the order of 0.01%; the quadratic mean error due to the measuring process only is of the order of 0.002-0.007%.

The above multilever instruments were used as grade 1 dynamometers for checking grade 2 dynamometers.

Figure 1 shows the schematic of a lever-type dynamometer with a top measuring limit of 50,000 kg-wt connected to a grade 2 hydraulic instrument of the M. K. Zhokhovskii system for the purpose of determining its metrological characteristics.

Processing of 147 measurements showed that the quadratic mean error of a measurement for determining the cross-sectional area of a working piston of the machine amounted to 0.02%.

Figure 2 shows a schematic of a lever-type dynamometer with a top measuring limit of 50,000 kg-wt connected to a grade 2 reference equipment of a lever type.

SUMMARY

1. Unequal arm lever systems with a gear ratio of 500-2,500 provide in an appropriate assembly the possibility of weighing 5,000 kg weights with an error of the order of 0.001-0.005%.

2. These lever systems can be used as reference grade 1 dynamometers for measuring a force with an error not exceeding ±0.05% of the measured value.

3. The adoption of the above lever dynamometers for metrological measurements will substitute in part the missing link in the measuring system, namely, the grade 1 dynamometers.

LITERATURE CITED

1. I. S. Gorpinchenko, Izmeritel'naya Tekhnika No. 1 (1957); No. 5 (1958).*
2. I. S. Gorpinchenko, Application of Unequal Arm Multilever Systems for Measuring Force and Mass [in Russian] (Author's report of his dissertation, Novosibirsk, 1959).

THE PROBLEM OF MEASURING HARDNESS

F. P. Volosevich

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 28-29, November, 1960

B. N. Vorontsov deals in his article** with the unsatisfactory supply to our industry of hardness measuring instruments.

The range of instruments for measuring hardness consists of two obsolete instruments types TSh and TK, which are unproductive in use and unsuitable for mass production.

Yet B. N. Vorontsov does not mention in his article either the large error of these instruments in measuring Brinell hardness or the deficiences of GOST (State Standard) 9012-59.

The total error of measuring Brinell hardness consists of several errors (those of the measure of hardness, the TSh instrument itself, the measuring microscope and the ball) and according to the Committee's instruction 235-56 should not exceed ± 3%.

The hardness tolerance for details at our plant normally corresponds to 0.3 mm of the indentation diameter. For instance, for a diameter of 3.5-3.8 mm or 2.8-3.1 mm the error of the measuring method amounts to 50% of the hardness tolerance of details. If one takes into account that the adjustment of different instruments can vary by ± 3%, it becomes clear that it is impossible to adhere to the tolerances specified in the instruction, especially if 2-3 instruments with different adjustments are used.

Section 6 of GOST 9012-59 states that the surface of the tested sample should have a flat finish which would produce the edges of the indentation with sufficient precision to be able to measure its diameter with the required accuracy.

* See English translation.

** Izmeritel'naya Tekhnika No. 4 (1960) [see English translation].

It would be advisable to mention here the grade of the surface finish suitable for testing.

Many plants do not adhere to section 13 of GOST 9012-59 according to which the diameter of the indentation should be measured in two mutually perpendicular directions, and determined as the arithmetic mean of these measurements. The difference in the two measurements of the diameter should not exceed 2% of the smaller diameter.

With a surface finish of grade 4-6 polished on a stone, the indentation has a jagged contour, which is difficult to measure in two mutually perpendicular directions and exceeds the deviation of 2% specified by the Standard.

Section 10 of GOST 9012-59 states that samples or details with curved surfaces tested by means of 10, 5 and 2.5 mm balls should have a flat test surface made on them, whose length and width should be at least 20, 10 and 5 mm respectively for the above dimensions of the ball.

The dimensions of 20, 10 and 5 mm are not specified with respect to measuring-microscope bases 50 mm in diameter. Hence, the indentation diameter is not in the same plane as the measuring-microscope base, and in order to obtain a clear image of the indentation contour additional adjustment (focusing) of the measuring-microscope is required, which is impossible in a 100% checking in mass production.

The base of the measuring microscope is placed on an unfinished and unstable surface which is often not parallel to the microscope.

A cylindrical detail 30 mm in diameter, for instance, will have a flat testing surface of 20 mm (chord), and a minimum indentation depth of 4 mm; this will damage the detail which will have to be scrapped, whereas according to the technical specification a 100% testing of hardness is required.

The use of a hardness-measuring method differing from the one shown on the drawing is not permissible, especially since the conversion tables of hardness numbers do not provide identical results in every case.

Editorial Note: In discussing the draft of GOST 9012-59 it was thought advisable not to mention in the Standard the grade of the surface finish. This was motivated by the absence of any marked effect of the surface finish on the Brinell hardness measurements, and also by the difficulty of determining the grade of surface finish under mass production measurements of hardness.

As far as the dimensions of the test surfaces are concerned, it should be noted that Section 10 of GOST 9012-59 specifies minimum lengths and widths of the surface; if a microscope with a larger base is used it is not forbidden to prepare test surfaces of corresponding dimensions. For details 30 mm in diameter a 2.5 mm ball should be used.

The articles of B. N. Vorontsov and F. P. Volosevich and the readers' letters show the interest aroused by the problems of using hardness-gauges and the technique of measuring hardness.

The editorial board requests the readers of this journal to express their opinion on these problems.

IMPROVEMENTS IN OSCILLOSCOPE OT-24-51

I. N. Petrov, E. A. Korshunov, and B. S. Chirkov

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Oscilloscope OT-24-51 constitutes a component part of a strain-gauge equipment which is intended for measuring at low frequencies without intermediate amplification. However, in testing heavy engineering, mining and metallurgical equipment it is often necessary to record on oscillographic paper not only the strain-

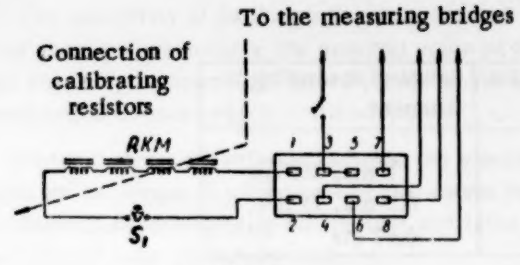


Fig. 1.

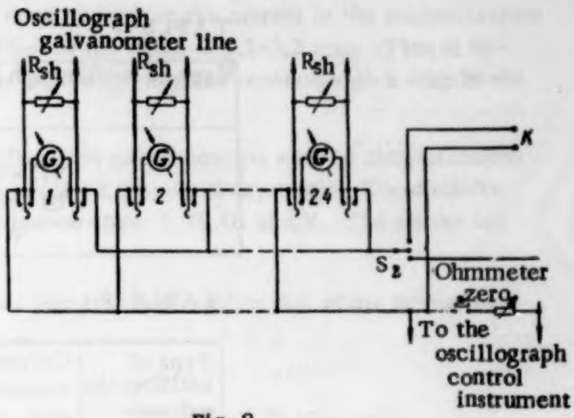


Fig. 2.

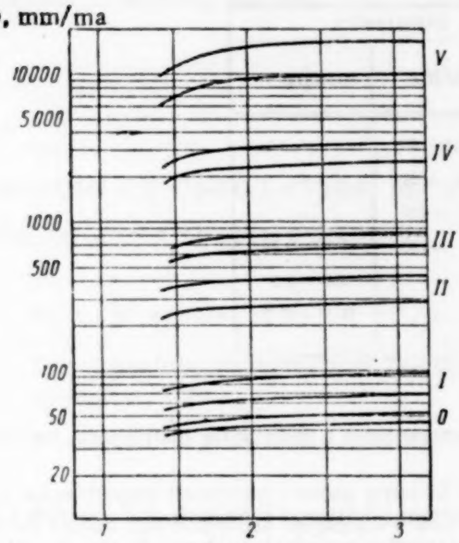


Fig. 3.

gauge transducer pulses, but also the electrical parameters of the drive, such as the armature current, excitation current, voltage at the generator or motor terminals, etc.

The sphere of application of this equipment can be enlarged by introducing certain changes in the electrical circuit of the oscilloscope.

The strain-gauge equipment OT-24-51 has several technical defects which make the adjustment and use of the equipment rather difficult. One of the defects is the use in the balancing unit and the oscilloscope of components with different supply voltages of 24 and 6 v. Moreover, the supply voltage of the bridges is not constant and must be varied between 5 and 50 v according to the resistance of the wire transducers used. Such a system requires the use of a large number of storage batteries, thus greatly increasing the weight of the equipment and making its use in laboratories rather difficult.

All the circuit components with the exception of the bridges can be fed, without prejudice to the equipment, from a rectified current supply obtained by means of a step-down transformer and a selenium or electronic 24 v rectifier with a total power of 250-300 w. Moreover, if necessary, a voltage stabilizer can also be included.

In order to change the supply of relay RKM in the balancing unit, the galvanometer, illuminators and the marker of time from 6 to 24 v, it is necessary to connect the four RKM relays in series instead of parallel, having provided them with two insulated terminals on the balancing unit as shown in Fig. 1. Similar changes are carried out in the balancing-unit cable terminal boxes.

The two 6 v, 3 w illuminating lamps type R-P-59 and the time-marker lamp are also connected in series. Yet another lamp of the same type as the above should be connected in series with them in the illuminating circuit. This lamp could be used for lighting the oscillograph measuring instrument, and could also serve as an indicator of the operation of the illuminating circuit which is of some importance under factory working conditions. The 6 v, 7.5 w lamp type SG2 of the synchronous motor is replaced by the normal 6 v, 3 w lamp type R-P-59 without affecting the quality of the time marks on the oscillogram. Another defect of the oscillograph consists in the difficulty of adjusting to the maximum sensitivity of the oscillograph galvanometers. The presence of the variable resistance R_{sh}, which shunts the galvanometer, impedes the calculation of the maximum deviation of the beam on the oscillograph paper for a given current.

This defect can be eliminated by substituting the oscillograph galvanometer in the measuring channel by an electrical measuring instrument, whose resistance should be approximately equal to that of the galvanometer and whose ranges should correspond to the galvanometer type in the manner shown in Table 1.

TABLE 1

Type of oscillograph galvanometer	Range of measuring instrument
0, I and II	5 ma, 300 mv
III and IV	0.5 ma, 75 mv
V	0.02 ma

TABLE 2

Type of oscillograph galvanometer	Galvanometer constant amp·m/mm	Sensitivity	
		mm/ma	mm/μa
0	$7.0 \pm 0.5 \cdot 10^{-6}$	46.3– 53	–
I	$4.2 \pm 0.7 \cdot 10^{-6}$	70 – 99	–
II	$1.0 \pm 0.2 \cdot 10^{-6}$	290 –440	–
III	$4.5 \pm 0.5 \cdot 10^{-7}$	690 –860	0.69–0.86
IV	$1.15 \pm 0.15 \cdot 10^{-7}$	–	2.6 –3.5
V	$2.5 \pm 0.5 \cdot 10^{-8}$	–	11.5 –17.2

When it is necessary to work with a large number of galvanometers a multiscale instrument, for instance, of the type of Ts315 or a similar instrument should be used.

For the convenience of switching-in the measuring instrument additional terminals and a switch can be mounted on the oscillograph. The schematic for connecting additional terminals is shown in Fig. 2. The additional terminals K and switch S_2 are mounted at the top right-hand side of the oscillograph, and the middle contact of switch S_2 is connected in series with the ohmmeter circuit.

The above circuit facilitates the balancing of bridges in strain-gauge measurements, and also serves to protect the oscillograph galvanometers from possible overloading while the required value of the shunt resistor R_{sh} and the building-out resistors in the measuring line are being selected.

It should also be remembered that both with the existing and the new oscillograph ohmmeter line circuit, a simultaneous operation of two or more push-button switches on the shunt panel short-circuits the measuring line.

In calculating the measuring circuits and selecting oscillograph galvanometers their nominal characteristics can be used.

The characteristic of certain types of galvanometers, including the one used in oscillograph OT-24-51, consists of the galvanometer constant, which, according to type, varies between $7.5 \cdot 10^{-6}$ to $2.0 \cdot 10^{-8}$ amp·m/mm. It is inconvenient to use this characteristic for practical calculations. A more convenient characteristic is the galvanometer sensitivity, i.e., the deflection of the beam on the oscillograph paper when 1 ma or 1 μa passes through the galvanometer, expressed as mm/ma or mm/μa.

For determining the galvanometer sensitivity the following formula can be used:

$$S_i = \frac{345}{10^6 C_i},$$

where S_i is the galvanometer sensitivity, mm/ma; C_i is the galvanometer constant, amp·m/mm.

The sensitivities of all five types of galvanometers used with oscillograph OT-24-51 are given in Table 2.

The sensitivity of oscillograph galvanometers can be changed by varying the current in the magnetization coils of these galvanometers; the nominal value of this current lies in the range of 3.1-3.3 amp. Thus it becomes necessary to determine the variations in the sensitivity of oscillograph galvanometers with a drop in the magnetization current, which could occur.

Figure 3 shows the relation between the sensitivity of oscillograph galvanometers and the magnetization current; for each type of galvanometer two curves are given which limit the sensitivity range. These curves were obtained experimentally for the four available types of galvanometers: 0, II, III and V. The curves for types I and IV were plotted by analogy.

These improvements of oscillograph OT-24-51 provide a wider sphere of application of the equipment, and facilitate its servicing and use.

PROCESSING OF OSCILLATION RECORDINGS BY THE QUADRATURE METHOD

P. S. Nikerov

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 31-32, November, 1960

In experiments involving various types of oscillations and pulsations it is often necessary to process a large number of curves characterized by period t and amplitude a in terms of periodic oscillations and corresponding characteristics of aperiodic processes (see fig., a). The investigator is often interested in the arithmetic mean t_m and a_m of these characteristics.

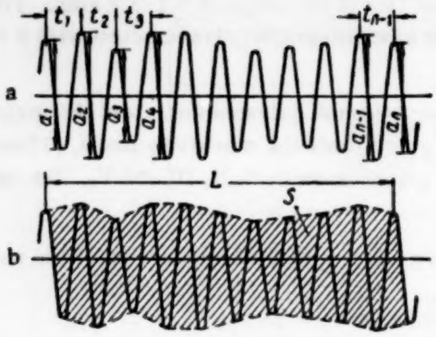
The determination of t_m is not difficult, since the value of $\overset{n}{\Sigma} t_i$ is obtained directly from the graph. In determining a_m it is necessary, however, to measure each half-period separately and add up all their values, which is a labor-consuming and tiring process. This difficulty becomes especially pronounced when the number of curves is large.

This work is simplified if the processing is carried out by the suggested quadrature method. The value of a_m is determined in this method as the quotient of the recorded "area" S divided by the length L.

By the "area" we understand the region S bounded at the top and at the bottom by the envelope drawn through the peaks (positive and negative) of the curve, and on the sides by the extreme portions of the curve itself (shaded on the drawing). The value of S can be easily determined by means of a planimeter. Moreover, in case of a sufficiently "close" recording there is no need for plotting the envelope, the planimeter point can simply be taken from one peak to the next.

Special test checking of a large number of such curves conducted during oscillatory investigations by the Odessa Institute of Naval Engineers showed that the discrepancy between the mean value of the amplitude determined by the precise, and this, method amounted to about 2%, i.e., it lies within the accuracy range of visual measurements. However, the speed of processing such curves when the quadrature method is used rises by a factor of 3-4, thus saving a lot of time normally used on such work.

The quadrature method is essentially approximate, and determines the value of a_m with a certain error. An analysis of various recordings of oscillations with different relations between their characteristics a and t has shown that the value of the error inherent in this method depends on the "uniformity" of the recording, i.e., on the amount by which the adjacent values of a_i and a_{i+1}, t_i and t_{i+1} differ from each other. A rising "irregularity" of the recording produces an increase in the error.



Thus, for instance, if in a recording all the characteristics a_i and t_i differ in their magnitude from the preceding and succeeding characteristics by a factor of 2 (which represents an extremely irregular recording), the error of the quadrature method will lie within the range of graphic measurement accuracy (up to 2%). For a greater irregularity this error is larger.

This method can be used for studying sustained oscillations of various systems, as well as in hydrology (in studying waves), in electrical and radio technology, etc.

THERMOTECHNICAL MEASUREMENTS

BASIC DEFECTS OF THE PROPOSED SYSTEM OF UNITS "m – kg – kg-wt – sec"

B. I. Pilipchuk

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 32-35, November, 1960

A complete clarity in technical thermodynamic notations does not yet exist owing to the fact that in many publications there is no clear distinction between the concepts of "mass" and "force." In attempting to eliminate this abnormal situation certain authors tend to establish new complicated systems of measuring units, instead of adhering strictly to the existing standards and measuring units. It seems, therefore, advisable to establish the theoretical error of such and similar proposals by analyzing one of these suggestions.

N. I. Belokon' asserts in [1] that by introducing a new concept of a "standard weight as a synonym of mass" it becomes possible to adopt a "system of units m – kg – kg-wt – sec," which is more "general" than the gravitational MKFS system. In view of the great importance of chosing a rational system of units let us examine this question in detail.

Standard weight. On page 14 of [1] it is stated: "The real weight F of a body is a force equal to the product of the body's mass and the actual acceleration of gravity g acting on that mass:

$$F = Mg. \tag{1}$$

"The standard weight G of a body is its weight for a certain assumed (standard) acceleration of gravity g_n:

$$G = Mg_n \tag{2}$$".

Thus we see that a "standard weight" is by definition a force. The statement on page 15 that the "standard weight of a body is determined .... by weighing it on a beam balance" is incompatible with its determination in (2) since it is well known that a beam balance provides a comparison of masses and not of forces of gravity. A "standard weight" can only be measured by means of a spring balance in that part of the world where the acceleration of gravity has the accepted standard value (approximately at a latitude of 45°).

Quantity of matter. In the same work on page 14 it is stated: "As a measure of the quantity of matter in any body it is possible to take the mass (M) of this body in the state of rest, or any other quantity which is a synonym of a mass of a body in a state of rest."

To use as a measure of the quantity of matter in a body its mass in a state of rest is not only possible but essential. The first definition which Newton used as a prerequisite for his three famous laws of classical mechanics (1687) states: "The quantity of matter is measured both by its density and volume. This quantity of matter I shall subsequently define by the name .... mass." Such an identification of the quantity of matter in a body with its mass was accepted by all physicists since Newton.

The theory of relativity has established that a mass m of a body measured in a system of coordinates with respect to which the body is moving with the velocity V differs from the mass m_0 of the same body at rest measured in a system of coordinates with respect to which this body remains at rest:

$$m = m_0 / \sqrt{1-(V/c)^2}, \quad (3)$$

where c is the speed of light. In the basic works of Einstein on his special and general theory of relativity the relation between mass and quantity of matter is not discussed. Since the mass at rest is an invariant, which relates the value of the mass of a body in different inertial systems of coordinates, it is only natural that this mass should be considered as a measure of the quantity of matter. Hence to use as a measure of the quantity of matter a "quantity which is a synonym of the mass at rest" as suggested by N. I. Belokon' is inadmissible. The whole problem is reduced to determining which quantity is a synonym of mass. We are not aware of the existence of such a concept, providing the ambiguous word "weight" in the sense of "mass" is excluded. Whereas N. I. Belokon' considers as a synonym of mass his newly-adopted concept of "standard weight" on the grounds that the standard acceleration of gravity is an accepted constant equal to $g_n = 9.80665\ \mathrm{m/sec^2}$. A standard weight (force) is not a synonym of mass and cannot express a quantity of matter (mass) in the form it has been defined by N. I. Belokon' on pages 14-15 of his book.

Unit of mass in the system "m – kg – kg-wt – sec." The abbreviated notations for systems of units consist of the first letters of the names of units of length, mass and time (the CGS and MKS systems) or units of length, force and time (the MKFS system). It is natural to expect that the abbreviated notation of a more general system of units "m – kg – kg-wt – sec" would list units of length, mass, force and time. However, this is not so. Table 1, p. 37 [1] does not mention a unit of mass among the six "basic mechanical and thermal units" of the new system, which includes units of length – the meter (m), of the quantity of matter – the kilogram (kg), of force – kilogram-force (kg-wt), unit of time – the second (sec), unit of temperature – degree (°C), and a unit of heat – kilocalorie (kcal). Only in an indirect manner on the basis of the fact that acceleration in formulas (1) and (2) is expressed in $\mathrm{m/sec^2}$ is it possible to conclude that the unit of mass in this system is the gravitational unit tem or inerta (1 tem = 9.80665 kg). A further analysis of this system reveals the existence of another unit of mass side by side with this one.

The meaning of letter G in technical thermodynamics. N. I. Belokon' introduces standard weight G into the ideal gas equation [1, p. 53]

$$PV = GRT,$$

where P is the pressure, $\mathrm{kg\text{-}wt/m^2}$; V is the volume, $\mathrm{m^3}$; R is the characteristic constant of the gas in question, kg-wt·m/kg·degree; T is the absolute temperature, °K.

The above formula is normally used in technical thermodynamics, but quantity G is simply known as "weight." Which of the two possible meanings, "force" or "mass," should be ascribed to this ambiguous word? An answer is easily obtained if the same equation is written in the form normally used by physicists:

$$PV = \frac{m}{\mu} RT,$$

where P is the pressure, $\mathrm{N/m^2}$; V is the volume, $\mathrm{m^3}$; m is the mass, kg; μ is the molecular weight, kg/mole; R is the universal gas constant, joule/mole·degree; T is the absolute temperature, °K.

The condition of the gas will not change if its volume and temperature remain constant, and the given quantity of gas is transported to any other planet with a different force of gravity. During this transportation the mass of gas remains constant, but its "weight" (force) changes. In order to make the former static equation applicable to gas after transportation it is necessary to ascribe to "weight" (or "standard weight") the meaning of mass and measure it accordingly in kilograms-mass (kg). Instead of using a physically correct terminology, the thermodynamic technicians, unconsciously paying tribute to a centuries-old tradition, preserve the philistine use of the word "weight," which leads, and must lead, at each step, to misunderstanding. Thus, for instance, going a step further, they call G/V specific gravity γ, although it is not by any means a "density of force" with a dimension of $\mathrm{kg\text{-}wt/m^3}$, but a "density of mass" (i.e., simply density in the ordinary sense) with a dimension of $\mathrm{kg/m^3}$, a quantity independent of the force of gravity wherever it may be used. Instances of incorrect understanding, and incorrect selection of units, could be extended still further, but we are only interested in stressing that in the majority of cases we are dealing with vestiges of pre-Newtonian notions, when the concepts of "mass" and "weight" were not yet separated. The confusion of units and quantities different in their

physical nature is considerably increased by the coincidence or approximate equality of their numerical values in the same or different systems of units. As an illustration let us quote in three different systems of units the density and specific gravity of water at 20°C in Moscow ($g = 9.81557$ m/sec^2). The density of water at 4°C is equal to $\rho_4 = 0.999972$ g/cm^3 = 1.000000 g/ml. The quantities which are often confused are denoted in the table by underlining.

Name of quantity		Numerical value of the quantity in units of a system		
		MKS	MKFS	CGS
Density (mass)	ρ_{20}	<u>998.201</u> kg/m^3	101.788 kg-wt·sec^2/m^4	0.998201 g/cm^3
Specific gravity (density of a force)	γ_{20}	9797.91 N/m^3	<u>999.108</u> kg-wt/m^3 0.999108 kg-wt/dm^3	979.791 d/cm^3
Relative density	ρ_{20}/ρ_4	0.998229		
Relative specific gravity	γ_{20}/γ_4	......		

The two meanings of "standard weight." The standard weight, which was defined as a force, is used in practice as a measure of mass. N. I. Belokon''s inconsistency, expressed in ascribing a double meaning to the concept of standard weight, can be demonstrated in yet another way. On page 15 in the explanations to formula (2) the value of acceleration of gravity is given as $g_n^{(1)} = 9.80665$ m/sec^2, whereas on page 35 a dimensionless factor* of "$g_n^{(2)} = 9.80665$ (m/sec^2)·(kg/kg-wt)" is given for calculating the "standard weight." The use of a similar notation for two numerically equal quantities of different dimensions is inadmissible anywhere, it must lead, and in fact did lead to confusion. The product of $Mg_n^{(1)} = M$ tem · 9.80665 m/sec^2 is a force expressed in kg-wt, whereas the product $Mg_n^{(2)} = M$ tem · 9.80665 is a mass $\underline{m}$ expressed in kg. Since quantity G was used in the gas equation as a mass, in fact only the second meaning of "standard weight" is being used.

Let us draw your attention to the following circumstance. The formula for converting mass M expressed in tem units to a mass $\underline{m}$ expressed in kg,

$$m\,\text{kg} = M\,\text{tem}\cdot 9.80665 = \left(\frac{m}{9.80665}\right)\text{tem}\cdot 9.80665,$$

resembles very closely the formula for calculating force F_n (we are not using the ambiguous notation of G adopted by N. I. Belokon') which provides a body of mass $\underline{m}$ kg a standard acceleration:

$$F_n\,\text{kg-wt} = M\,\text{tem}\cdot 9.80665\ \text{m/sec}^2 = \left(\frac{m}{9.80665}\right)\text{tem}\cdot 9.80665\ \text{m/sec}^2.$$

The right-hand sides of the equations only differ by their dimensions. It is sufficient to forget about this difference or, simpler still, to cancel by the dimensionless factor 9.80665 omitting the dimension of the resulting numerical unit, in order immediately to obtain the relation "1 kg = 1 kg-wt," which is pointed out by N. I. Belokon' himself on page 15. Elsewhere he also says "it is obvious that the measuring units kg-wt and kg are numerically equal ...." (p. 35). The measuring units of all the physical quantities without exception are numerically equal, but only units of the same quantities can be equated or compared.

Duality of the units of mass and energy. Since the quantity of matter, in other words the mass, is measured in kg, N. I. Belokon''s system has two units of mass, that of tem for mechanical calculations and that of a

* The ratio of two units of the same dimension is always dimensionless. Since the gravitational unit of mass has the dimension of kg-wt·sec^2/m, the dimension of this factor is a ratio of two units of mass kg/tem, i.e., it is dimensionless.

kilogram-mass (kg) for thermodynamic calculations (calculations of static equations, specific quantities, i.e., quantities referred to a unit of mass, etc.). Similarly for measuring heat, in addition to the derived unit of the MKFS system, the kilogram-meter (kg-wt·m) there is an independent "basic" unit, the kilocalorie (kcal). In a correctly derived system of units the existence of two units for the same quantity is impossible owing to the very principle of forming derived units. N. I. Belokon''s "system of units" is not a system but a collection of units which are basic for a thermodynamic technician. N. I. Belokon' considers that his "system has an important advantage ... in the manner of determining the quantity of matter (standard weight), specific weights, specific volumes, etc., independently of the value of the actual acceleration of gravity." From the above exposition it follows that this advantage is in no way connected with the adoption of the concept of "standard weight" and of a new "system of units," but can be ensured exclusively by a correct understanding of the value of "weight G."

Possible methods for selecting dynamic units. Let us, finally, examine one common problem — what means are there for introducing dynamic units in a system of units. According to Newton's second law, a force acting on a body is directly proportional to the rate of change of the body's momentum mV:

$$F = \alpha \frac{d}{dt}(mV).$$

If we consider the mass to be constant (the case of very small velocities as compared to that of light), we can simply write: $F = \alpha ma$, where α is the acceleration.

In a coherent system of units the dimensionless coefficient of proportionality should be equal to unity and the formula take the simplest form taught to everyone at school. In order to convert the coefficient into unity there are three, and only three, methods: to select a unit of force with respect to the units of mass and acceleration; to select a unit of mass with respect to the units of force and acceleration; to select a unit of acceleration with respect to the units of mass and force.

Newton, the unit of force of the International System of Units, has been derived according to the first method: a newton is a force which acting on a body of a mass of 1 kg gives it an acceleration of 1 m/sec^2.

The unit of mass in the gravitational MKFS system of units is selected according to the second method: the gravitational unit of mass (tem or inerta) is the mass of a body which under the effect of a force of 1 kg-wt moves with an acceleration of 1 m/sec^2.

The third method is hardly used at all, since it is natural to assume that the units of length and time have been established beforehand and do not require revision when dynamic units are derived. The third method conceals unlimited possibilities, since it provides the means of eliminating the coefficient of proportionality in an infinite number of ways, by simultaneously changing the units of length and time. A consistent system on this basis was derived, for instance, by P. P. Kopnyaev in 1927 [2]. If only the simplest case is considered when one unit is varied at a time, there are two possible solutions: to adopt a new unit of length equal to 9.80665 m, preserving the existing unit of time, or to adopt a new unit of time equal to $1 : \sqrt{9.80665}$ sec, preserving the existing unit of length. In either case the body of a mass of 1 kg acted upon by a force of 1 kg-wt will move with unit acceleration expressed in the new units of acceleration which will be derived from the changed units of length and time.

If new units of mass and force are selected simultaneously, but the unit of acceleration is unchanged in order to preserve the condition of coherence, it will inevitably be necessary to abandon the usual formulation of the second law of dynamics $F = ma$, replacing it by a more general formula $F = \alpha ma$. (In a system of units in which the unit of mass is 1 kg, and the unit of force 1 kg-wt, the coefficient of proportionality will be equal to 1/9.80665. In order to avoid any misunderstanding we should like to draw your attention to the fact that this system is not N. I. Belokon''s "system of units," in which tem is the unit of mass used for mechanical calculations and kg used for thermodynamic calculations, i.e., in which the uniformity of measurements is not preserved in different branches of physics).

SUMMARY

1. It is impossible to adopt as a synonym for mass the concept of "standard weight" which is a product of mass by acceleration, since mass is an independent concept differing from that of force. Notes which state

that "the standard weight is determined on beam balances" also lead to a confusion of concepts of force and mass, since beam balances measure mass.

2. The suggested identification of the quantity of matter with the "standard weight" brings us back to pre-Newtonian times when the word "weight" was still generally used as a synonym for "mass."

3. The suggested artificial distinction between the concepts of "mass" and "quantity of matter" by expressing them in separate units (the unit of mass being 1 tem = 9.80665 kg, and the unit of the quantity of matter being 1 kg) cannot be justified by any theoretical or practical considerations. Since Newton's time mass characterizes the inertia and the force of gravity in bodies, and is used for measuring the quantity of matter in bodies.

4. The historically formed tradition in applied thermodynamics to use simultaneously a kilogram as a unit of mass and force provides no reasons for adopting a more general "m – kg – kg-wt – sec" system than the existing gravitational MKFS system. A consistent development of a system of units based on four fundamental units of length, mass, force and time requires the abandonment of coherence and the necessity of introducing into the second law of dynamics a dimensionless coefficient of proportionality. By preserving the normal formulation of this law without a coefficient of proportionality, N. I. Belokon' has in fact abandoned the development of a system of units and confined himself to a combination of the units of two systems – the MKS and the MKFS systems.

5. The use of two units of mass: the tem for mechanical calculations (for instance, for calculating force), and kg for purely thermodynamical calculations (for instance, for calculating specific quantities), as well as the use of two units of energy, the kilogram-meter and the kilocalorie, confirms that N. I. Belokon' 's "system of units m – kg – kg-wt – sec" is not a system of units at all.

6. In order to avoid the existing confusion in the notations of applied thermodynamics it is necessary to:

a) avoid departures from existing state standards for systems of units and units for measuring physical quantities;

b) abandon the attempt at preserving the existing abnormal condition and unjustifiably adopting the name of "system" for a set of primary units;

c) strive to make the authors avoid the word "weight," clearly distinguish between the concepts of "mass" and "force," and correctly name and denote the kilogram-mass as kg and the kilogram-force as kg-wt.

LITERATURE CITED

1. N. I. Belokon', Thermodynamics [in Russian] (Gosénergoizdat, Moscow and Leningrad, 1954).
2. P. P. Kopnyaev, Izmeritel'naya Tekhnika No. 6 (1955).

PYROMETER WITH AN AUTOMATIC SIGNALING OF THE REGISTRATION INSTANT

I. G. Butivchenko

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November, 1960

The most accurate measurements of the temperature of liquid steel and cast iron are attained by means of a thermoelectric pyrometer, which consists of an immersion thermocouple and an electronic potentiometer.

The author of this article has developed and adopted in production an automatic device for signaling the instant when the temperature of the liquid metal is registered by means of these measuring instruments.

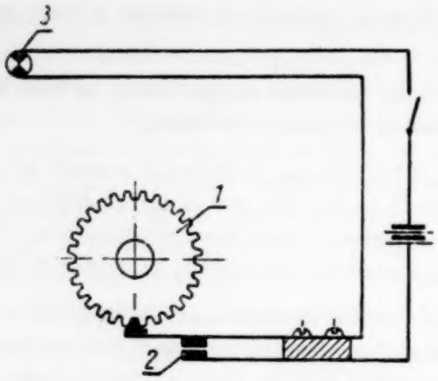

Fig. 1.

The instant of signaling coincides with the stopping of the reversible motor which balances the measuring bridge of the potentiometer. This signaling prolongs the life of the thermocouple quartz tips by preventing them from remaining too long in the liquid metal, shortening the duration of each measurement, and making it possible for one person to perform all the measurements. When temperatures of the liquid metal are measured without an automatic signaling of the registration instant errors are often incurred by a premature withdrawal of the thermocouple from the metal before a stable balance of the potentiometer bridge is attained.

Figure 1 shows the schematic of the additional device which is incorporated in the automatic potentiometer. A toothed disk 1 is fixed inside the instrument on the axle of the reversible motor reduction gear. This disk rotates with the motor rotor, thus continuously closing and opening contacts 2, which are connected to the supply circuit of signaling lamp 3. This produces a flashing of the lamp during the rotation of the motor.

The signaling lamp is mounted on the thermocouple jacket (a steel tube) which makes it easily visible.

As soon as a balance of the potentiometer bridge circuit is attained, the motor stops rotating and the signaling lamp remains either connected or disconnected, i.e., it stops flashing, thus indicating that the potentiometer readings should be taken and the thermocouple withdrawn from the metal. A 3 v signaling lamp fed from a storage battery is used for this purpose.

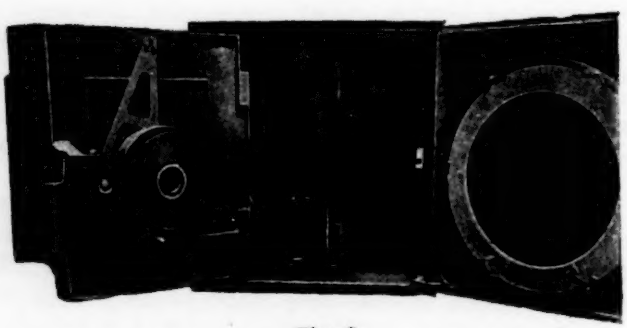

Fig. 2.

Figure 2 shows the position of toothed disk 1 and contacts 2 inside the potentiometer.

WIDER APPLICATION OF THERMAL METERS IN OUR NATIONAL ECONOMY

N. I. Zhukovskii

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November, 1960

The Tallin Plant of Measuring Instruments has produced on the basis of a theoretical design by Prof. Yakimov a commercial model of a thermal meter type TS-1 and organized its mass production.

Thermal meter TS-1 is intended for measuring the amount of heat produced or consumed by a power installation, in which water serves for conducting heat. This instrument provides a record of the amount of heat delivered to a consumer.

The thermal meter operates in conjunction with any volume or velocity-operated hot water meter with a caliber of 15 to 300 mm, a maximum pressure of 12 kg-wt/cm^2 in the heat conducting supply mains, a water temperature of 30 to 150°C in the supply mains, and a water temperature of 30 to 70°C in the return mains.

The principle of operation of the thermal meter consists in finding the instantaneous values of the product of the flowing water by the temperature difference between the supplied and returned water, and in integrating these products with respect to time.

The thermal meter consists of two main units: a dilatometric differential thermometer and a frictional integrator.

The instrument has the following basic parameters.

A range of temperature differences between the supplied and returned water of 0-100°C calibrated in 2°C. An error in measuring temperature differences of ± 2°C. A top limit of the water-meter reading amounting to 9999 m^3. A top reading of the thermal meter of 999 cal $\cdot 10^9$. The maximum error in the thermal meter readings for a temperature difference between the supplied and returned water of 20-100°C (without counting the water meter) amounts to ± 4%. The error of readings for temperature differences of 0-20°C is not specified. Its weight is 6 kg. Overall dimensions are 480 × 140 × 140 mm.

The thermal meter has passed state tests at the D. I. Mendeleev VNIIM (All-Union Scientific Research Institute of Metrology) and been approved for production and field testing on a wide scale.

Additional extensive tests carried out by the Committee of Standards, Measures and Measuring Instruments under factory conditions showed that the thermal meters are stable and reliable in operation and provide stable readings.

The plant has installed a test rack for mass-production testing of the manufactured instruments, and another rack for checking the instruments now in use.

The test rack for checking instruments now in use is completely up-to-date (automatic temperature control, automatic stopping of the disk, small dimensions, an efficient layout). This rack can be used in state inspection laboratories for measuring technique and by consumers who use these thermal meters.

Despite the production by the Tallin Plant of 3,000 such meters in 1959, they are not being extensively used in thermal networks.

One of the reasons impeding the adoption of these instruments by our industry is the lack of close ties between the plant and the consumers using these instruments, and the consequent lack of information on the operation of these instruments in the hands of the consumers.

The state inspection laboratories of measuring equipment should check the work of these instruments in the heating networks of towns and speedily inform the plant and the Committee of all the defects in the thermal meters now in use.

The D. I. Mendeleev All Union Scientific Research Institute of Metrology should develop suitable methods and compile instructions for checking these instruments.

The state inspection laboratories of measurement equipment should be supplied with the equipment necessary for checking the thermal meters.

In order to reduce the errors in the meters the Tallin Plant should speed up the experimental work in modernizing the prismatic unit of the instrument and substituting the material of the tubes.

A wide use of thermal meters will provide an effective record of the quantity of heat produced and consumed in our national economy.

ELECTRICAL MEASUREMENTS

DIGITAL DISPLAY TRANSISTORIZED BRIDGE

V. N. Malinovskii and R. R. Kharchenko

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November, 1960

The existing digital display dc bridges for measuring resistance use electromechanical elements (electrical motors, step-by-step switches and relays). It is obvious that such devices are relatively slow in operation and have short life. Therefore, the use of transistors in automatic digital display instruments has great possibilities, since they possess a number of valuable properties, such as high reliability, small dimensions, small power consumption, high operating speeds and a long life.

The authors of this article investigated the possibility of designing digital display bridges using exclusively contactless semiconductor elements. On the basis of this investigation a digital display bridge circuit was designed.

The basic elements of this circuit determining the accuracy of bridge balancing are switches which switch the resistances in the balancing arm of the bridge.

The schematic of the switch used in the above bridge is shown in Fig. 1. The switch consists of three junction-type silicon diodes D202 (the use of junction silicon diodes of other types is also possible), two auxiliary ballast resistors R_1, R_2, and one source of auxiliary voltage, common to all the switches in the balancing arm, and connected between point 3 and "ground." The control voltage is fed between points 4 and "ground." The switched resistance is denoted by r_0. The voltage of the auxiliary source is chosen so as to make the potential at point 3 smaller in its absolute value than that at point 1.

In order to explain the operation of the switch let us examine the volt-ampere characteristic of the diode (Fig. 2). If voltage V is applied to the diode in its conducting direction and a current I is flowing through it, the diode may be represented, if the current variations are small, by an equivalent circuit consisting of a series-connected emf e_0 and a dynamic resistance r_d, whose values can be found graphically from the volt-ampere characteristic. The value of e_0 is determined as the voltage along the X-axis taken from the origin to the point of intersection of the X-axis with the tangent to the volt-ampere characteristic drawn through the operating point of the diode. The value of r_d is determined as the tangent of the angle between this line and the Y-axis; r_d decreases with a falling current which flows through the diode, and for a current of several tens of milliamperes has a value of the order of several ohms. Variations of the diode temperature have little effect on the value of r_d; the effect of temperature on e_0 is considerable (0.05 v for 30°C). If a reverse voltage is applied to the diode a current i_{rev} will flow through it, whose value depends but little on the applied voltage. With a rising temperature the diode current i_{rev} increases; however, even for 50°C current i_{rev} does not exceed $(3-5)\cdot 10^{-8}$ amp.

It should be noted that the diodes for the switch should be selected by their reversed current, which should not exceed $(1-2)\cdot 10^{-8}$ amp for a diode temperature of 20°C and a reversed voltage across the diode of the order of 10 v. Thus a closed diode may be represented as a generator of current i_{rev}.

When a positive control voltage is fed to point 4 (Fig. 1) all the diodes D_1, D_2 and D_3 become conducting and pass corresponding currents. Resistors R_1 and R_2 are calculated so as to make equal control currents flow through diodes D_2 and D_3. The values of the equivalent emfs e_0 of diodes D_2 and D_3 will then have opposite

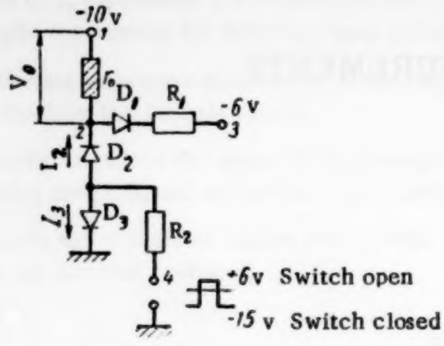

Fig. 1.

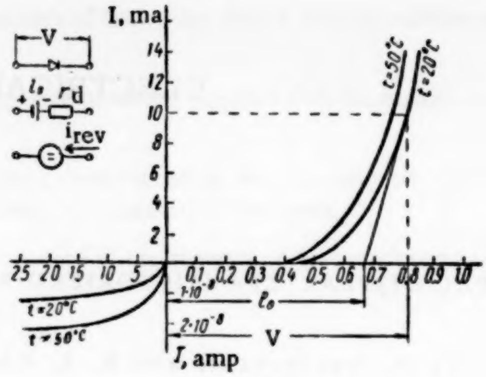

Fig. 2.

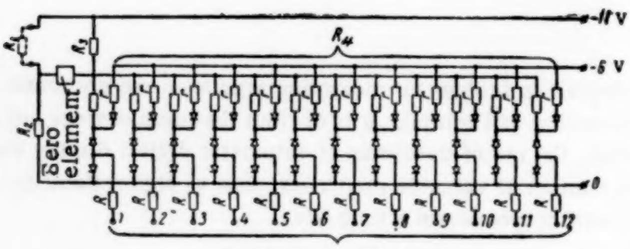

Fig. 3.

signs and compensate each other. The small residual voltage difference between them can be compensated by an adjustment of resistor R_1. Thus in a closed switch circuit it is possible to reduce the equivalent voltage between point 2 and "ground" to the order of e_{res} = (1-3) mv. If the auxiliary and control voltages are taken from the same source (mains), small variations in the mains voltage (up to ± 10%) do not produce any noticeable variations in e_{res}. The full voltage across an open switch is equal to

$$V_{os} = e_{res} + r_d (I_3 - I_2),$$

where I_2 and I_3 are currents flowing through diodes D_2 and D_3 respectively when the switch is open.

The error due to the switching of resistance r_0 is represented by expression $V_{os}/V_0 = \lambda$. It will be seen from this expression that the accuracy of the bridge using the above switches will be, with other conditions remaining equal, the higher the larger the value of V_0.

If a negative control voltage is fed to point 4 with its absolute value larger than the voltage at point 1 (closed switch), all the diodes of the switch will be blocked. Moreover, the reversed current of diode D_3 flows through "ground" to the source of the controlling voltage and does not reach the measuring circuit. The reversed currents of diodes D_1 and D_2 are subtracted from each other at point 2, and their difference which flows through resistance r_0 does not exceed about $1 \cdot 10^{-8}$ amp, which is only comparable to the stray leakage currents. Therefore it can be considered that the switch almost completely disconnects the circuit of resistance r_0.

Figure 3 shows the circuit of the measuring part of the bridge with the switches. The bridge is designed for one range of resistance measurements R_1 = 0-100 ohm in steps of 0.1 ohm.

The bridge is balanced by means of a set of resistors in the arm R_4. The balanced condition of the bridge is represented by the equation

$$R_1 = R_2 R_3 \sum_{K-1}^{12} a_K g_K ,$$

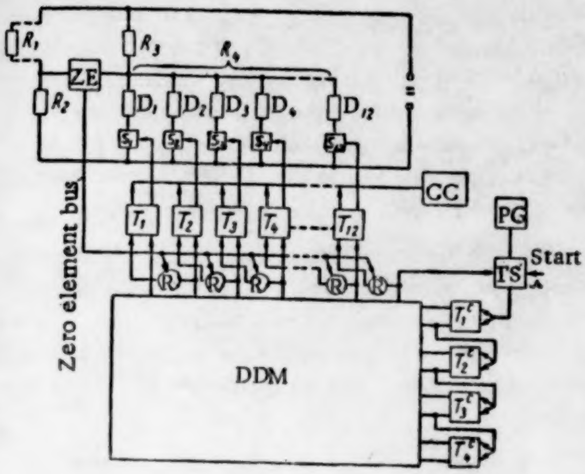

Fig. 4.

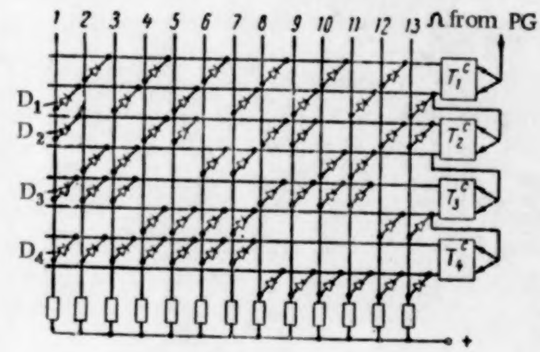

Fig. 5.

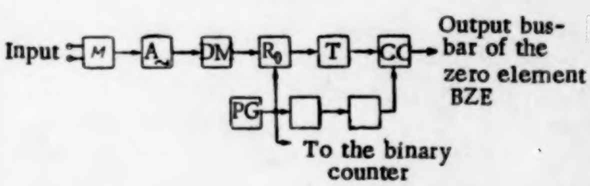

Fig. 6.

where

$$\sum_{\kappa=1}^{12} a_\kappa g_\kappa = \frac{1}{R_4};$$

a_k are the coefficients which assume the value of 0 or 1 depending on the condition of the switch which commutates the corresponding conductance g_k in the bridge arm R_4.

All the switches have a common point, which considerably simplifies the control circuit. The conductances in the balancing arm are divided into three decades, each of which contains elements with weighing factors of 2, 4, 2, and 1.

The full layout of the circuit is shown in Fig. 4. The binary counter consisting of triggers $T_1^C - T_4^C$ controls the operation of the diode distributing matrix DDM (Fig. 5) designed for sequential connection of triggers $T_1 - T_{12}$ which control switches $S_1 - S_{12}$ in the balancing arm of the bridge. In the initial condition the voltage across all the output busbars 1,...,13 of the matrix (Fig. 5) is equal to zero with respect to the nominal "ground." The first pulse received by the counter from the pulse generator PG flips trigger T_1^C from position zero to position 1. This blocks diode D_1 (Fig. 5) and a voltage appears on the first output busbar of the matrix, since diodes D_2, D_3 and D_4 are nonconducting due to triggers T_2^C, T_3^C and T_4^C being in the zero position. The voltage which appeared across busbar 1 of the matrix operates switch S_1 through trigger T_1 (Fig. 4).

The second pulse from generator PG produces a voltage across the second busbar of the matrix, and makes the voltage across the first busbar fall to zero. The voltage across the second busbar of the matrix operates through trigger T_2 switch S_2, and simultaneously through rectifier R and trigger T_1 disconnects switch S_1, if the preceding operation of switch S_1 had produced an overcompensation of the bridge circuit, thus making all the rectifiers R conducting by means of the zero element. In the opposite case (undercompensation of the bridge circuit) switch S_1 remains operated, since rectifiers R are nonconducting. The next voltage pulse across the third busbar of the matrix operates switch S_3 through trigger T_3, and if necessary disconnects S_2.

In a similar manner balancing proceeds until switch S_{12} is operated ("weighing" method). The voltage across the last, thirteenth, busbar of the matrix disconnects through trigger T_{12} switch S_{12}, if its operation had overcompensated the bridge circuit, and simultaneously locks the trigger switch TS, thus stopping the transmission of pulses from generator PG to the binary counter. The balancing process of the bridge circuit is thus completed.

The zero element (ZE on Fig. 4) consists of a dc amplifier whose block schematic is shown in Fig. 6. All the circuit elements are completely transistorized. Modulator M, consisting of two transistors, operates at the modulating frequency of 5 kc. The ac amplifier $A_\sim$ consists of twin transistors and has a gain of the order of 10^4. The demodulator DM operates as a phase-sensitive stage. Rectifier R_0 is controlled by the pulses from generator PG; each of these pulses received at the input of the binary counter (Fig. 4) simultaneously blocks

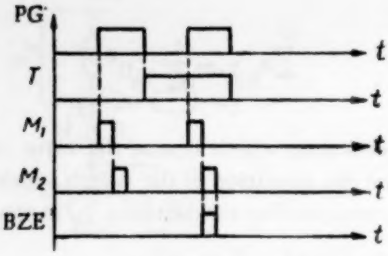

Fig. 7.

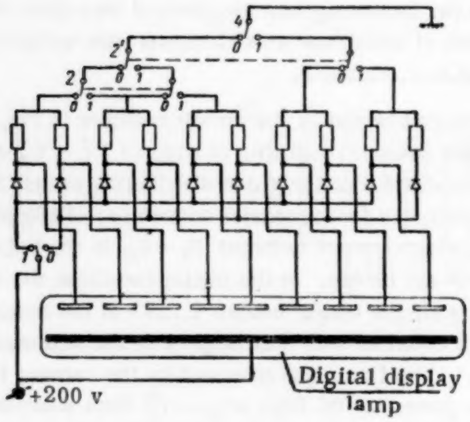

Fig. 8.

rectifier R_0. Trigger T functions as a memory cell at the output of the zero element and controls through the coincidence circuit CC the voltage at the output busbar of the zero element: pulses from generator PG are fed to the coincidence circuit CC through two kipp oscillators (M_1 and M_2 on Fig. 7) with a time delay of the order of 1 msec.

Let us now examine the operation of the zero element in the bridge circuit. The first pulse from the generator PG connects, as it has been stated, switch S_1; three conditions may then arise in the bridge circuit: undercompensation, overcompensation or correct balancing.

In the first case at the output of the demodulator DM there appears a voltage which flips trigger T to position 0, producing a low voltage on the trigger side of the coincidence circuit CC. The next pulse from generator PG blocks rectifier R_0, since at the instant S_2 should be operated there appears at the output of the zero element a short transient pulse which operates switch S_2 through the diode distributing matrix. The same pulse is fed to the coincidence circuit CC with a time lag of 1 msec, which is necessary for the completion of the transient processes in triggers $T_1^C - T_4^C$. However, this will not produce a voltage at the output busbar of the zero element, since the voltage on the trigger side of the coincidence circuit CC is equal to zero. Rectifiers R (Fig. 4) are blocked and switch S_1 remains connected.

In case of overcompensation there also appears at the output of demodulator DM a voltage which flips trigger T to position 1, producing a control voltage on the trigger side of the coincidence circuit CC input. This will not produce a voltage at the output busbar of the zero element, since the voltage on the generator PG side of the control circuit CC input is equal to zero. The second pulse from generator PG will again block rectifier R_0, operate through the diode differential matrix DDM switch S_2 and reach the coincidence circuit CC with a time lag of 1 msec. This will produce at the output busbar of the zero element a voltage operating rectifiers R (Fig. 4). Of all the DDM matrix busbars only the second one will have a voltage, which will be transmitted through a conducting rectifier R to the second input of trigger T_1, will return the trigger to its zero position and thus disconnect switch S_1. The time sequence diagram for pulses in the zero element is given for this case in Fig. 7.

If the bridge circuit is accurately balanced at the instant switch S_1 is operated, the signal at the input of the zero element will be equal to 0, but a random interference at its input may flip trigger T either to the 0 or 1 position, depending on the sign of the interference. Thus switch S_1 may either remain operated or disconnected.

It is obvious that if switch S_1 remains operated, all the remaining switches will be disconnected, since the connection of each subsequent switch inevitably leads to overcompensation of the bridge circuit. However, if switch S_1 is disconnected, the balancing will be completed with an accuracy of the smallest compensation step provided.

On completion of the bridge balancing the code registered by the position of triggers $T_1 - T_{12}$ (code converter CC is shown in Fig. 4) is transmitted to a computer, which converts the binary-decimal code of the triggers into a decimal code for visual display on digital lamps. Figure 8 shows a circuit for converting the code for one decade. The conversion is made by means of miniature electromechanical relays type RCM-2.

SUMMARY

The testing of the model has shown that the instrument operates reliably and provides resistance measurements in the range of 0-100 ohm with an error of 0.2 ohm.

It should be noted that, with a small internal resistance of the bridge supply source, the reactance of the measured resistances has no effect on the measurement results, since during balancing the current in the bridge arm containing R_1 is not changed.

The above investigation can be used for designing and mass production of miniature automatic transistorized digital-display ohmmeters.

THERMOELECTRIC COMPARATOR FOR MEASURING SMALL ALTERNATING CURRENTS AND CHECKING MICROAMMETERS

T. B. Rozhdestvenskaya and A. M. Teplinskii

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 41-44, November, 1960

Radioelectronics, wire communications and several special spheres in engineering require instruments for measuring extremely small currents of higher frequencies in the sonic and ultrasonic range. In recent years the instrument making plants in the USSR and abroad have started making such instruments for measuring currents from a few tens of microamperes upwards. In the majority of cases these microammeters are of the rectifier or thermoelectric types, although at present new electronic instruments are also being produced, for instance, milliammeter F58 of the "Tochélektropribor" Plant.

Despite the fact that the best of the existing microammeters have a relatively low, grade 1.5 accuracy, according to the new GOST (State Standard) 1845-59, which comes into force on May 1, 1961, their checking must be carried out with an error five times smaller than that of the instrument, which presents considerable difficulty in view of the small currents under consideration.

The existing Soviet reference equipment for higher frequencies and thermoelectric comparators type TÉK-1 developed by the VNIIM (All-Union Scientific Research Institute of Metrology) [1] have until recently provided highly accurate measurements of alternating currents above 3-5 ma.

Measurement of smaller currents becomes difficult for two reasons:

a) the sensitivity of thermal converters falls sharply with a decreasing measured current;

b) the error of current measurements rises due to an increase in capacitance leakages, stray inductive and capacitive coupling and electromagnetic interference.

In 1959 the VNIIM produced a model of a new thermoelectric comparator type TÉKF-1 which can measure alternating currents from 20 μa upwards with an error in the range of $\pm(0.3\text{-}0.5)\%$.

Comparator circuit. The basic element of the comparator (Fig. 1) consists of a mass produced indirectly heated thermocouple type TVB-1; for a nominal current of 1 ma it develops a thermal emf of 2.5 mv, and its heater resistance is about 500 ohm. The heater of the thermocouple 1 is connected into the ac circuit and the thermal emf produced by the measured current is amplified by photoamplifier 2, and registered by means of galvanometer 3 and compensator 4.

Next, the thermocouple heater is switched over to a dc circuit whose current is adjusted until the same thermal emf is obtained as for the alternating current. The measured value of the direct current is assumed to

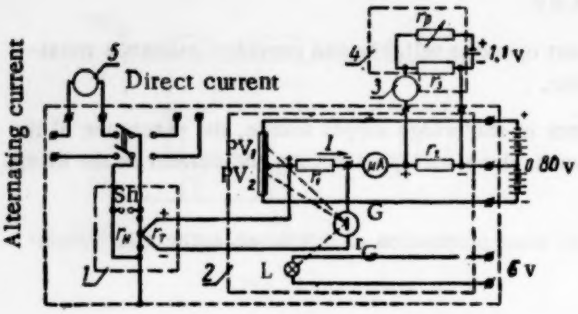

Fig. 1.

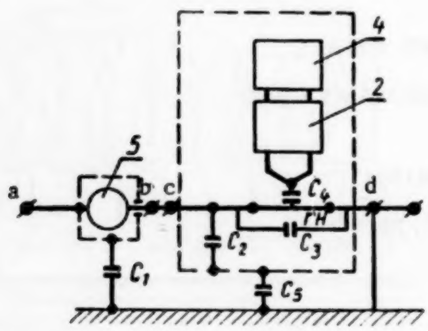

Fig. 2.

represent that of the alternating current with the comparator errors taken into consideration. Thus the comparator uses the well-known method of measuring accurately the effective value of the alternating current by comparing it with a direct current [1, 2].

In order to increase its sensitivity the comparator is supplied with a photoamplifier 2 type F17/1 made by the "Vibrator" Plant [3]. The output of the photoamplifier is connected to resistor r_2 and a dc 50 μa microammeter μA, which is intended for checking the operation of the measuring circuit.

The supplies for the amplifier photovaristors PV_1 and PV_2 are obtained from a center tapped 80 v anode battery. The incandescent lamp L is fed from a stabilized 6 v source.

Compensator 4 of the simplest type is used as a "memory device" and is connected together with galvanometer 3 to the terminals of resistor r_2. By means of rheostat r_p the current is controlled through resistor r_3, across whose terminals a voltage drop is thus produced in the opposite direction to the voltage drop Ir_2 produced by the photoamplifier current I in resistor r_2.

The thermoelectric comparator TĚKF-1 is mounted in a small cabinet of 500 × 300 × 110 mm, whose top panel carries the knobs of switches, the terminals for connecting the supply circuits and instruments under test 5, and the control microammeter μA. The top panel is supplied with a lid, by unscrewing which access is obtained to the thermocouple. The lower part of the top panel carries the photoamplifier. The body of the comparator is screened.

Comparator sensitivity. The sensitivity of the thermal comparator depends on the choice of the thermocouple, photoamplifier, galvanometer and other elements of the circuit.

The electromotive force e_T of the thermocouple is related to the current I_H in its heater by the equation

$$e_T = kI_H^n,$$

where k and n are constants.

The sensitivity of the thermocouple is represented by

$$S_T = \frac{de_T}{dI_H} = knI_H^{n-1}.$$

For the majority of thermocouples it is possible to assume that n = 2; then

$$S_T = 2kI_H. \tag{1}$$

We shall consider the photoamplifier amplification factor A_p as the ratio of the increase of output current I to the infinitely small rate of increase of current I_G flowing through the coil of galvanometer G:

$$A_p = \frac{dI}{dI_G}.$$

The amplification factor of the photoamplifier F17/1 used in the comparator is equal to 250.

A thermocouple emf increment of Δe_T produces a variation in the amplifier output current ΔI equal to

$$\Delta I = \frac{A_p}{r_T + r_G + r_1} \Delta e_T, \tag{2}$$

where r_T is the resistance of thermocouple TVB-1; r_G is the resistance of galvanometer G; r_1 is the compensating resistance.

In a similar manner an increment in the amplifier current produces a deflection of the output galvanometer 3 through an angle

$$\Delta \alpha_2 = S_{g_2} \frac{r_3}{r_3 + r_{g_2} + r_3} \Delta I, \tag{3}$$

where S_{g2} is the sensitivity of the output galvanometer 3; r_{g2} is the resistance of galvanometer 3; r_3 is the compensating resistor in the circuit of compensator 4.

From (1), (2) and (3) the total sensitivity of the thermocomparator becomes

$$S_t = \frac{d\alpha_2}{dI_n} = S_{g_2} \frac{2 r_3 A_p k}{(r_T + r_G + r_1)(r_3 + r_{g_2} + r_3)} I_n. \tag{4}$$

The sensitivity in terms of the relative variation of the input variable is

$$S_{rt} = S_{g_2} \frac{r_3 A_p k}{50 (r_3 + r_{g_2} + r_3)(r_T + r_G + r_1)} I_n^2 \ \mathrm{mm}/\%. \tag{5}$$

When a TVB-1 thermocouple and a GPZ-2 (S_{g2} = 200 mm/μa) galvanometer are used, the sensitivity of the comparator is equal to 8 mm/μa when a minimum current of 20 μa is measured.

With a rising value of the measured current the sensitivity increases proportionately to the square of the current (5).

The sensitivity of the comparator does not change if the voltage across the photovaristors is reduced from 60 to 20 v and across the illuminating lamp L from 7 to 4 v. However, short voltage pulses at the terminals of lamp L produce a noticeable flicker in the reading of output galvanometer 3. This makes it necessary to feed the lamp L from a stabilized source of supply.

In order to raise its zero stability the photoamplifier is mounted on a shock-absorbing base.

A further rise in stability is attained by introducing overdamping [4] for galvanometer 3. Experience has shown that for a damping factor of β = 3-3.5, the sensitivity of the comparator decreases only by 5-10%, and the damping time rises from 3 to 10 sec, which does not affect essentially the operation of the comparator. The above measures reduce instability to ± 1 mm.

Measurement errors depend on the errors in comparing the alternating and direct currents by means of the comparator, and on the error of measuring the direct current equivalent in its thermal effect to the alternating current.

One of the comparison errors consists in the effect of the direction of the dc flow through the heater on the thermal emf. This relation differs for different TVB-1 thermocouples. For a nominal heater current the error is small (0.01-0.03%) but it rises with a decreasing heater current in some of the thermocouples to 0.5-1%. The dc polarity error is almost completely eliminated by a double measurement with a straight and reversed direction of the current.

When the comparator is connected to the high frequency circuit, errors may arise due to stray capacitances shunting certain parts of the measuring circuit, to skin effect, etc. Capacitance couplings between the elements of the circuit may lead to the current passing through the measured instrument differing from the one measured by the comparator.

An equivalent circuit of the connections of the measured instrument 5 and the comparator is shown in Fig. 2 (the notations are the same as in Fig. 1).

The heater terminal $\underline{d}$ is grounded and a screen is connected to it. The terminals of the instrument under test and the comparator which are not connected to the screen are connected to each other by means of the shortest possible leads bc. In this way capacitances C_1 and C_5 do not affect the measurement error.

The errors due to the self-capacitance C_3 of the heater and the capacitance C_4 between the heater and the thermocouple proper, as well as that due to the skin effect, are small, and according to calculations do not exceed 0.01% up to a frequency of 1 Mc.

The largest effect on the measurement error is produced by the capacitance between the current-carrying conductor and the comparator screen which is denoted on the drawing by C_2 and shunts the thermocouple heaters. Capacitance C_2 is decreased by reducing to a minimum the distance between the measured instrument and the thermocouple heater. In the comparator this capacitance is of the order of 12 $\mu\mu$f.

It can easily be shown that the error due to the above capacitance can be approximately represented by the formula

$$\gamma = \frac{\Delta I_{\text{н}}}{I_{\text{н}}} 100 \simeq 50 r_{\text{н}}^2 \omega^2 C_2^2 \,\%, \tag{6}$$

where $\omega = 2\pi f$ is the angular frequency.

Up to a frequency of 1 Mc this error according to calculations from (6) does not exceed 0.1%.

In order to extend the measuring range to currents above 100 μa, the thermocouple heater is shunted by a nonwire-wound resistor (Fig. 1). The comparator is supplied with a set of 8 shunts with nominal values of 2 to 500 ohm which provide measurements up to 20 ma. Measurements have shown that these shunts have time constants τ from 0 to 4 mμsec.

The error due to shunting calculated from the well-known formula [1] does not exceed ± 0.01% at 1 Mc.

The error due to the reactance of the heater and skin effect also does not exceed 0.01% at 1 Mc.

With a decreasing frequency of the current the error decreases proportionately to the square of the frequency. The top limit of the thermoelectric comparator TĖKF-1 for which the frequency error can be neglected is taken to be 200,000 cps.

When measuring small currents a considerable effect on the measurement error can be produced both by ac and by dc leakage currents, external electromagnetic fields, etc.

All the leads connected to the TĖKF-1 instrument, all auxiliary elements, and the instrument under test are screened. Each screen is connected separately to the grounded end of the thermocouple heater.

In order to reduce leakage currents of the thermocouple heater, it is mounted on polystyrene supports. The insulation resistance of the current-carrying conductors with respect to the screens must not be less than 10^{12} ohm.

The error of the comparator in measuring alternating currents was checked experimentally by comparing it with the thermistor and thermoelectric (TĖK-1) comparators developed by the VNIIM.

The thermistor comparator measures currents from 20 μa upwards with an error of ±0.3% at 50,000 cps.

Tests have shown that for currents from 50 μa to 1 ma the difference in the measuring results did not exceed 0.1-0.25%. For currents smaller than 50 μa the difference increased to 0.45%.

If the above frequency errors be neglected, the error of comparison is determined in the main by random errors, which were found by repeated measurements of the same direct current.

The quadratic mean error $\sigma / I_H \cdot 100$ calculated from 60 measurements of each value was for a heater current of 100 μa – 0,07%; for 60 μa – 0,12%, and for 20 μa – 0,21%.

The value of random errors depends on the instability of the photoamplifier, thermocouple, output galvanometer and other elements of the comparator. The main contribution to this error comes from the instability of the photoamplifier, whose noise level remains the same for any value of the measured current. Hence the relative effect of its instability rises with a decreasing measured current.

The error in measuring the direct current adjusted to be equal to the alternating current depends on the instrument used for this purpose. If a potentiometer with standard resistors is used the error does not exceed a few hundredths of one per cent.

SUMMARY

On the basis of the tests made with the thermoelectric comparator TĚKF-1 and the evaluation of the whole measuring process, including the error of the dc potentiometer type R2/1, the total error of the instrument should be considered not to exceed ± 0.3% when measuring currents of 50 μa, and not to exceed ± 0.5% when measuring currents from 50 μa to 20 μa in the range of 20 to 200,000 cps.

Comparator TĚKF-1 is suitable for checking and investigating frequency errors of the existing microammeters in the sonic and ultrasonic ranges.

LITERATURE CITED

1. K. P. Shirokov, Comprehensive Equipment for Testing Ammeters and Voltmeters at High Frequencies, Trudy VNIIM 24 (84) (1954).
2. F. L. Hermach, J. Res. NBS 2, 48 (1952).
3. A. N. Kasperovich, Izmeritel'naya Tekhnika No. 5 (1959).*
4. B. P. Kozyrev, Uspekhi Fiz. Nauk 54, No. 2 (1951).

MEASURING THE SELF-CAPACITANCE OF INDUCTION COILS*

Yu. A. Brammer

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 44-45, November, 1960

The range of frequencies for which coils are immune from any undesirable resonance effects is determined by the self-capacitance C_0 of the coils. This capacitance can have a value ranging from a few to several hundred picofarads.

At present, in order to determine C_0 the resonance frequency of the circuit consisting of the coil under test and a variable capacitor C_{vr} is measured, and relation $1/f^2 = F(C_{vr})$ is determined by means of which C_0 is found. This method is inconvenient and labor-consuming.

The author of this article has suggested a method for measuring the capacitance of coils which is to a great extent free from these defects.

A known sinusoidal voltage is impressed on the coil (Fig. 1) whose self-capacitance has to be determined, and the reactive component I_{r1} of the coil current is measured.

A similar measurement is made with a voltage whose amplitude and frequency differ by a factor of n from the similar parameters of the voltage which was first used.

* See English translation.

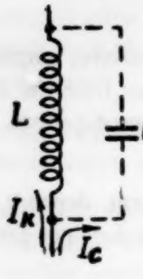

Fig. 1.

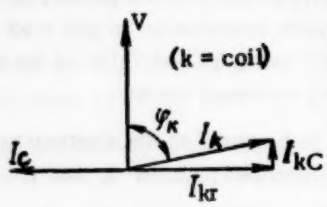

Fig. 2.

Since both the inductive reactance of the coil $x_L = \omega L$ and the voltage across it change in the second measurement as compared with the first by the same factor, the reactive component of the currents in both instances remains almost the same. But the capacitive current $I_C = V\omega C_0$ changes in the second measurement as compared with the first by a factor of ω^2. Hence, the self-capacitance of the coil can be determined from the algebraic difference of the reactive currents $\Delta I_r = I_{r1} - I_{r2}$ providing they are measured at the specified voltages.

The relation between ΔI_r and C_0 is derived in the following manner.

According to the vector diagram (Fig. 2) the reactive current in the coil circuit is

$$I_r = I_\kappa \sin \varphi_\kappa - I_C = \frac{V\omega L}{r^2 + (\omega L)^2} - V\omega C_0,$$

where r is the resistance of the coil, or

$$I_r = V\left[\frac{1}{\omega L\left(1 + \frac{1}{Q^2}\right)} - \omega C_0\right],$$

where Q is the Q-factor of the coil.

The difference in the reactive components of currents measured at voltages V_1 and V_2 is

$$\Delta I_r = V_1\left[\frac{1}{\omega_1 L\left(1 + \frac{1}{Q_1^2}\right)} - \omega_1 C_0\right] - V_2\left[\frac{1}{\omega_2 L\left(1 + \frac{1}{Q_2^2}\right)} - \omega_2 C_0\right],$$

where ω_1 and ω_2 are the frequencies of voltages V_1 and V_2; Q_1 and Q_2 are the Q-factors of the coils at these frequencies. Since $V_2/V_1 = \omega_2/\omega_1 = n$, we have

$$\Delta I_r = \frac{V_1}{\omega_1 L}\left[\left(\frac{1}{1 + \frac{1}{Q_1^2}} - \frac{1}{1 + \frac{1}{Q_2^2}}\right) + \omega_1^2 L C_0 (n^2 - 1)\right]. \quad (1)$$

The first term in the right-hand side of the equation does not depend on C_0 and represents the error due to the difference in the Q-factor of the coils at frequencies ω_1 and ω_2.

However, this error is insignificant, since $1/Q_1^2 \ll 1$ and $1/Q_2^2 \ll 1$.

For instance, for $Q_1 = 30$, $Q_2 = 10$, $C_0 = 2\,\mu\mu f$, $L = 1$ mh, $f_1 = 500$ kc and $n = 10$, the first term of (1) only amounts to 0.5% of the second term, and for the same parameters at $f_1 = 200$ kc it amounts to 3%.

Hence, (1) can be written with sufficient accuracy as

$$\Delta I_r = U_1 \omega_1 C_0 (n^2 - 1),$$

i.e., for given values of V_1, ω_1 and n the self-capacitance of a coil is determined by the algebraic difference of the measured currents' reactive components.

HIGH AND ULTRAHIGH FREQUENCY MEASUREMENTS

PORTABLE, HIGHLY STABLE, TRANSISTORIZED OSCILLATOR WITH SEVERAL FIXED FREQUENCIES

K. I. Nazarov

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 45-47, November, 1960

We describe below a portable, miniature, highly stable, laboratory oscillator with several fixed frequencies developed and produced by the author of this article in cooperation with B. A. Kazantsev and V. F. Vashchenko. The instrument is reliable in use and has an error not exceeding $\pm 1 \cdot 10^{-6}$ (the block schematic of the instrument is given in Fig. 1).

This oscillator is intended for calibrating separate scales of wavemeters, standard signal generators and other instruments with continuously variable frequencies. It can be used as a source of highly stable fixed frequencies whose values are spaced at a ratio of ten in the range of 10 cps to 1 Mc. The range of measurements is extended by means of harmonics.

The heating up period before measurements amounts in an ambient temperature of 20 ± 20°C to no more than 60 min. The instrument operates from 220 v ac mains; its power consumption is no more than 10 w. Its weight is 5 kg.

In order to avoid the effect of ambient temperature changes and variations in the supply voltage, the quartz crystal resonator of 100 kc (in a vacuum container), the transistor and other elements of the oscillator are placed inside the thermostat 3, which is maintained at a constant temperature with deviations not exceeding ± 0.1°C; the instrument is fed with a stabilized voltage of 1.5 v from a transistorized rectifier.

By means of cooling or heating this thermostat, it is possible to maintain in it, owing to the use of semiconductor thermal elements, any temperature with the deviations given above in the range of ± 25°C with respect to the ambient temperature. It is also possible to stabilize the temperature at +20°C.

This circumstance makes the use of the instrument easy, since in existing quartz oscillators the temperature of the thermostat is maintained only by means of heating up in the limits of 65-75°C, and a stabilized temperature is attained only after at least 2 hr of operation. Moreover, it is impossible to operate without such a long preheating period, owing to the temperature-frequency coefficient of the quartz crystal.

The stabilization of the thermostat temperature at +20°C also has the following advantages: the stabilization time is considerably reduced, which is particularly important for measurements under laboratory conditions when the temperature of the surrounding air is close to +20°C; when high measuring accuracy is not required, it is possible to use the instrument without stabilizing the thermostat temperature, for instance, with instruments for whose testing the relative error of the reference generator must not be more than $\pm 1 \cdot 10^{-5}$ at a temperature of the ambient air of 20 ± 10°C; the operating conditions of the transistor and other elements of the oscillator circuit placed inside the thermostat are improved; and the consumption of electrical energy for stabilizing the temperature of the thermostat is reduced.

For stabilizing the temperature at +20 ± 0.1°C, a transistorized electronic regulator is used.

The use of transistors instead of electron tubes [1] in the heat control circuit (Fig. 2) simplifies the circuit and makes it more reliable. Moreover, it is no longer necessary to have heater and anode supply circuits. The

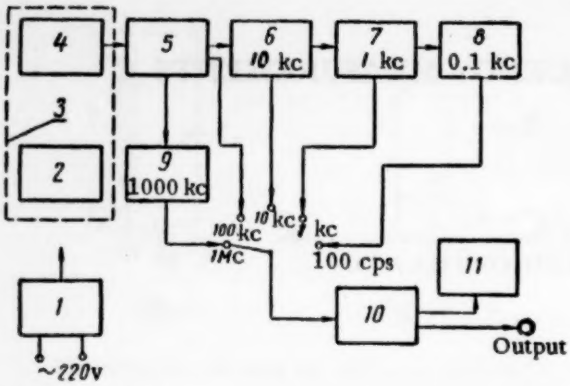

Fig. 1. 1) Power pack; 2) heat regulator; 3) thermostat type TP-1; 4) quartz-crystal master oscillator 100 kc; 5 and 10) emitter-followers; 6,7 and 8) junction-transistor frequency dividers; 9) junction-transistor frequency multiplier; 11) output diode indicating voltmeter.

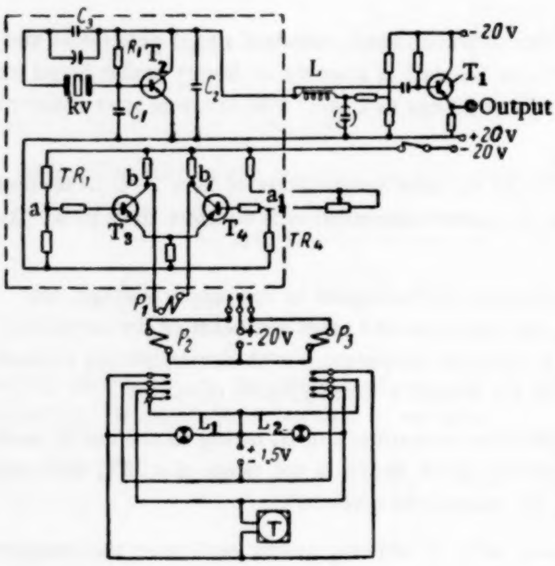

Fig. 2.

Properties	The new oscilla-tor	Instruments KG-A and KG-B
Weight of the instrument in a carry-ing box, kg	8	84
Total number of com-ponents	127	288
Electron tubes	–	22
Transistors	28	10
Tuned circuits	5	10
Relative error of measure-ment	$\pm 1 \cdot 10^{-6}$	$\pm 1 \cdot 10^{-6}$
Heating up time, min	60	90
Power con-sumed from the mains, w	10	85

placing of these transistors inside the thermostat which maintains the temperature at +20°C practically eliminates the variation of their characteristics due to changes in the ambient temperature.

The two temperature controlled thermistors TR_1 and TR_4 with resistance temperature coefficients of 4-6% per 1°C are connected in a bridge circuit. The bridge imbalance voltage due to variations of temperature is amplified by transistors T_3 and T_4 and fed to relay P_1, which by means of relays P_2 and P_3 changes the direction of current in the thermoelectric battery, transferring it from a cooling to a heating operation or vice versa.

The frequency is divided by means of a stabilized, cathode-coupled, multivibrator circuit with junction transistors. This circuit provides a stable frequency division at a ratio of 1:10. The collector tuned circuits improve the shape of the generated signals.

The frequency multiplier consists of a tuned amplifier using junction transistors in a common emitter circuit [2].

A series type circuit is used for stabilizing the voltage supply.

The use of junction transistors of various types and two stabilitrons provides optimum matching between the stabilizer stages and a high efficiency in its operation.

The test results of this circuit were highly satisfactory.

The above circuits provide a regulation factor of the order of 1,000.

The thermal battery of the thermostat is supplied from a full wave rectifier which uses crystal diodes type D305 [3]. It provides a voltage of 1-1.5 v for a current of 8-10 amp.

The instrument is assembled in the form of a small unit. The oscillator is mounted together with a quartz crystal on a disk,made of organic glass and a foam plastic,inside the thermostat. The thermoregulator components are also fixed on this disk. The transducer is mounted 1-2 mm from the bottom of the thermostat. Such a location of the transducer provides a small temperature inertia and excludes the possibility of the thermal battery overheating during the initial heating up.

The oscillator and thermal regulator terminals are mounted on the lid of the thermostat together with the spindle of the oscillator trimming capacitor.

The thermostat is mounted on a chassis, which also serves as a radiator for the thermal battery, whose heat exchange with the surrounding medium is raised by means of side panels.

The components of the frequency dividers and multipliers, and the emitter-followers are mounted on an organic glass plate.

Frequency trimming is attained during operation by means of a potentiometer in the collector supply circuit of the oscillator. The potentiometer spindle is taken out of the front panel. This spindle carries a disk with a circular scale which can be viewed through an opening in the front panel.

The trimming of the multivibrator multiple frequencies is made by means of potentiometers mounted inside the instrument.

The advantages of this instrument as compared with similar instruments using electron tubes consist of the simplicity of its design, reliability in operation, small dimensions and weight, and small power consumption.

The number of fixed frequencies provided by this oscillator is equal to the sum of those provided by two similar instruments types KG-A and KG-B.

By comparing the properties given in the table attached of the highly stable fixed-frequency oscillator with those of a similar type it is easy to see its advantages with respect to size, design, and operational qualities.

An experimental check of the oscillator frequency stability gave the following results: relative error with an ambient temperature of 20 ± 20°C and a heating up of the thermostat for 60 min did not exceed $\pm 1 \cdot 10^{-6}$; when operating with the automatic temperature control system of the thermostat disconnected (without preliminary heating up) and an ambient temperature of 20 ± 10°C the relative error did not exceed $\pm 1 \cdot 10^{-5}$.

SUMMARY

The above highly-stable transistorized oscillator can be widely used in radio measuring laboratories, and especially in mobile laboratories, for testing equipment in situ. It can be assembled in other ways involving a smaller size and weight.

LITERATURE CITED

1. Semiconductors in Science and Engineering [in Russian] (Acad. Sci. USSR Press, v. 2, 1958).
2. R. A. Valitov, A. I. Aleksandrov, and L. I. Akulov, "Transistorized Measuring Instruments" in collection: "Semiconductors and Their Application" edited by Ya. A. Fedotov [in Russian] ("Sovetskoe Radio" Press, v. 2, 1957).
3. S. B. Yuditskii, Germanium and Silicon Semiconductor Rectifiers [in Russian] (Materials of the All-Union Conference on the Application of Semiconductors in Industry, 1958).

EQUIPMENT FOR OSCILLOSCOPE OBSERVATION OF THE TRAVELING-WAVE FACTOR IN ULTRAHIGH FREQUENCY CHANNELS

E. A. Stakhov

Translation from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 47-49,
November, 1960

The adjustment and checking of waveguide unit channels at ultrahigh frequencies is a painstaking operation and takes a long time.

Measurements can be speeded up by special installations with an oscilloscopic display of measurement results.

For measuring the traveling-wave factor over a narrow band of frequencies it is possible to construct relatively simple devices on the basis of the reflectometer principle.

In installations for oscillographic observation of the traveling-wave factor a most effective use can be made of a reflectometer circuit with two directional couplers. As compared with reflectometer circuits using four probes, this circuit has the following advantages: firstly it provides smaller irregularities in the channel, and secondly, it only requires two detectors with identical characteristics instead of four [1, 2].

For a directional coupler the maximum and minimum voltage values at the indicator are respectively equal to

$$E=|K|\cdot|E_1|\cdot\left(\frac{|\beta|\cdot|\Gamma_1|}{1\pm\Gamma_1\Gamma_2}\mp|\beta|\cdot|\Gamma_3|\mp|d|\right), \tag{1}$$

where K is transfer coefficient of a directional coupler; E_1 is the voltage fed from the UHF generator; Γ_1, Γ_2 and Γ_3 are the reflection factors of the element under test, the coupling slit and the matched load respectively; d is the directivity factor of the coupler;

$$|\beta|^2=1-|K|^2-|\Gamma_2|^2.$$

A good coupler has, over a narrow frequency band, a directivity factor of 30-35 db. Since $|\beta|$ approaches unity, the phase error and the error due to the imperfect matching of the coupler load for a directivity of 35 db lead to measurement errors of the order of 4% [3].

The block schematic of the oscilloscope installation for observing the traveling-wave factor is shown in Fig. 1. The circuit contains two identical directional couplers 3 and 4, one of which serves to measure the incident and the other the reflected wave. Klystron oscillator 2 type 51-I is modulated by means of rectangular pulses from modulator 1. Detector voltages are fed through amplifiers 6 and 7 type 28-IM to the horizontal and vertical inputs of oscilloscope 8 type ÉO-6M. The circuit is connected to the waveguide device 5 under test.

In the presence of a modulated UHF signal, two bright spots appear on the oscilloscope screen. The straight line which can be imagined connecting these two points has a slope which is determined by the reflection factor of the device under test:

$$|\Gamma| = \frac{V_{rfl}}{V_{inc}} = \frac{S_1 V_1}{S_2 V_2} = \tan\alpha, \tag{2}$$

where S_1 and S_2 are the amplification factors of the vertical and horizontal amplifiers respectively (for the same sensitivity of the vertical and horizontal deflecting plates of the oscilloscope); V_1 and V_2 are the voltages at the input of the amplifiers.

The latter expression holds when $S_1 = S_2$. If amplifiers of the type 28-IM are used there will be no difficulty in maintaining equal gains, since these instruments are provided with an internal gain adjustment with an error not exceeding 3%.

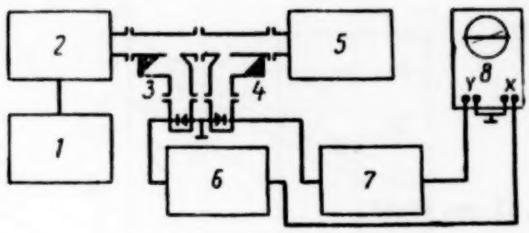

Fig. 1.

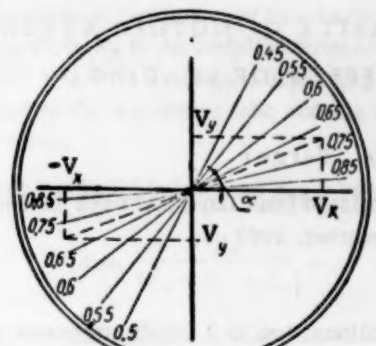

Fig. 2.

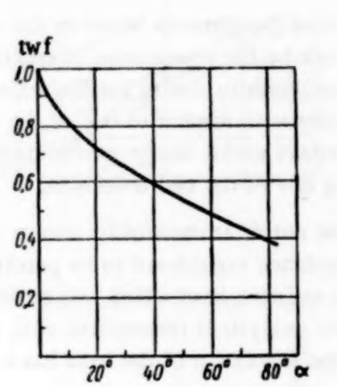

Fig. 3.

Since the reflection factor has a single-valued relation to the traveling-wave factor, it is possible to use expression (2) for calibrating the equipment in traveling-wave factors.

The reading is taken off a scale plotted on a transparent celluloid plate which is placed in front of the oscilloscope screen (Fig. 2).

If the equipment is used for production control it is sufficient to draw on the plate two lines corresponding to the production tolerances of the traveling-wave factor.

The equipment can be calibrated by means of a measuring line. It should be noted that the detectors comprised in the circuit before calibration need not be identical, since the correction to the voltage ratio which determines the traveling-wave factor will be accounted for during calibration. This permanent correction can also be made to include the correction due to $S_1 \neq S_2$. This will make it possible to use amplifiers with unequal gains and couplers with different directivities, which is very convenient for measuring very large or very small values of the traveling-wave factor.

For an experimental determination of the circuit characteristics we produced an equipment working in the 3 centimeter range. We used in the equipment directional couplers from instrument type 60-I and an oscilloscope type ÉO-6M. The displacement of the spots through an angle of 5° which, as it will be seen from the graph (Fig. 3), is easily observable on the oscilloscope screen was equivalent, in the model produced by us, on an average to a variation in the traveling-wave factor of 0.05 for measurements in channels with a traveling-wave factor of 0.4 to 0.85. Calibration was made by means of a measuring line type 33-I.

SUMMARY

The above equipment made it possible sharply to decrease the time required for measuring the traveling-wave factor, provided a graphic representation of the measurements, and speeded up the adjustment and checking of waveguide channels.

LITERATURE CITED

1. Modern Cathode-Ray Oscilloscope, Collection of articles edited by I. S. Abramson [Russian translation] (Foreign Literature Press, part 2, 1951).
2. I. V. Lebedev, Ultrahigh Frequency Technology and Instruments [in Russian] (MÉI Press, Moscow, 1956).
3. Measurement Technique at Centimeter Wavelengths, translation from English edited by G. A. Remez [Russian translation] ("Sovetskoe radio" Press, v. 1, 1949).

NONLINEARITY OF CUTOFF ATTENUATORS DUE TO THE EFFECT OF LOADING

L. A. Birger

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 49-51, November, 1960

The nonlinear loss in a cutoff attenuator expressed as a function of the distance between the electrodes is observed in the initial stages of the plunger movement, and caused both by the appearance of spurious types of waves and by the effect of loading. Below we give computations of nonlinearity due to loading effects. Although by means of this computation it is only possible to evaluate nonlinearity with respect to one of the two phenomena which can produce it, this evaluation, nevertheless, provides certain useful design information, and helps to analyze experimentally obtained data on nonlinearity by excluding one of the two unknowns.

The loading effect has been dealt with in [1] by representing the cutoff attenuator by means of an equivalent long line with its propagation constant and its characteristic impedance considered to be purely imaginary. Quantitative evaluations were obtained only for one special case of a resistive load which was equal to the modulus of the cutoff attenuator characteristic impedance. The above analysis is incomplete and, what is more important, leads to erroneous conclusions since, as it will be shown, the reactance of the load has a considerable effect on the nonlinearity of the cutoff attenuator.

In order to avoid a certain artificiality by using a concept of a long line with an imaginary characteristic impedance, let us use for our calculations an equivalent circuit consisting of lumped constants (Fig. 1). The use of such a circuit is justified by the fact that the phase velocity of wave propagation in a cutoff attenuator is equal to $v_p \to \infty$.

The circuit shown in Fig. 1 is characteristic of attenuators with capacitative coupling (Fig. 2), whose coupling impedance is $Z_c = 1/j\omega C_c$; Z_Γ and Z_H are the impedances of circuits connected to the exciting and receiving electrodes with their capacitances C_{e1} and C_{e2} taken into consideration; E is the voltage at the exciting electrode for $C_c = 0$ (receiving electrode withdrawn). Other types of cutoff attenuators can be represented by similar circuits by means of the usual circuit transformation methods.

It will be shown below that the knowledge of the exact parameters of the equivalent circuits is not essential. They will be replaced in the final formulas by the attenuator initial loss which can be determined experimentally.

In a cutoff attenuator the coupling impedance Z_c is purely reactive:

$$Z_c = jX_c.$$

The basic property of a cutoff attenuator consists in the phenomenon that at very small distances between the electrodes, when only the operative type of wave is essential, the absolute value of X_c varies exponentially:

$$X_c = X_0 e^{\alpha(L - L_{it})} = X_0 e^{\alpha l}, \tag{1}$$

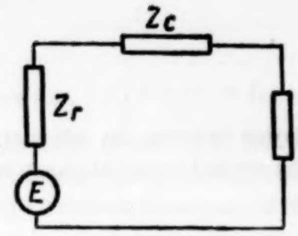

Fig. 1.

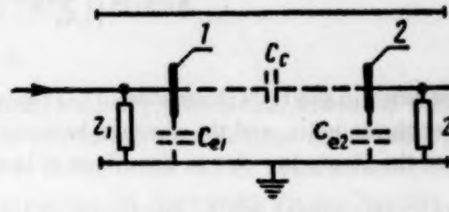

Fig. 2.

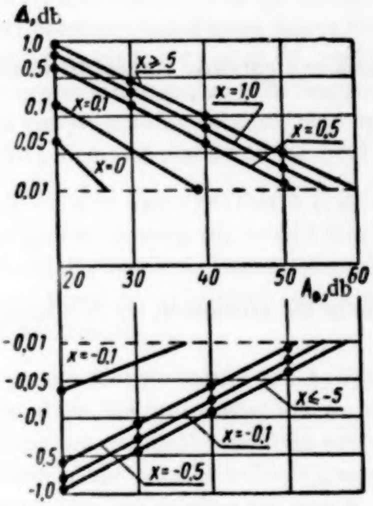

Fig. 3.

where $l = L - L_{it}$ is the variation in the distance between the electrodes with respect to a certain initial distance $L_{it} \neq 0$; X_0 is the coupling impedance corresponding to $l = 0$; α is a constant depending on the cross section of the attenuator tube and the type of the operating wave.

Power P_H dissipated in load Z_H is equal to

$$P_H = \frac{E^2 R_H}{|Z_c + Z_\Gamma + Z_H|} =$$

$$= \frac{E^2 R_H}{X_0^2} e^{-2\alpha l} \frac{1}{\left(\frac{R_H + R_\Gamma}{X_0 e^{\alpha l}}\right)^2 + \left(1 + \frac{X_H + X_\Gamma}{X_0 e^{\alpha l}}\right)^2}. \tag{2}$$

Let us denote

$$R_H + R_\Gamma = R; \quad X_H + X_\Gamma = X. \tag{3}$$

Let us also note that for not too small a distance between electrodes $|Z_c| \gg |Z_\Gamma + Z_H|$, i.e.,

$$\frac{R}{X_0} e^{-\alpha l} \ll 1; \quad \frac{X}{X_0} e^{-\alpha l} \ll 1. \tag{4}$$

Then

$$P_H = \frac{E^2 R_H}{X_0^2} e^{-2\alpha l} \left[1 - \left(\frac{R}{X_0} e^{-\alpha l}\right)^2 - \frac{2X}{X_0} e^{-\alpha l}\right]. \tag{5}$$

The loss introduced by the attenuator for a distance between the electrodes changing from l_1 to l_2 amounts to

$$A = 10 \log \frac{P_{H1}}{P_{H2}} = 8.69\,\alpha\,(l_2 - l_1) + 10 \log \frac{1 - \left(\frac{R}{X_0} e^{-\alpha l_1}\right)^2 - \frac{2X}{X_0} e^{-\alpha l_1}}{1 - \left(\frac{R}{X_0} e^{-\alpha l_2}\right)^2 - \frac{2X}{X_0} e^{-\alpha l_2}}. \tag{6}$$

Let us assume that the variation in the attenuator setting is sufficiently large, so that $e^{\alpha l_2} \gg e^{\alpha l_1}$. This assumption makes it possible to replace the denominator in (6) by unity. By expanding the logarithm into a series we obtain the formula

$$A = 8.69\alpha\,(l_2 - l_1) - \Delta, \tag{7}$$

where

$$\Delta = 4.34\left[\left(\frac{R}{X_0}e^{-\alpha l_1}\right)^2 + \frac{2X}{X_0}e^{-\alpha l_1}\right]. \tag{8}$$

The first term in the right-hand side of (7) represents the linear relation between the attenuator loss, expressed in logarithmic units, and the distance between the electrodes. The second term (Δ) characterizes the deviations from the linear law due to the effect of loading.

Let us calculate initial loss A_0 introduced by the attenuator at setting l_1:

$$A_0 = 10\log\frac{P_{H0}}{P_{H1}}, \tag{9}$$

where P_{H0} is the power dissipated in the load $Z_c = 0$, which corresponds to a galvanic contact between the electrodes.

From the circuit in Fig. 1 we find

$$P_{H0} = \frac{E^2 R_H}{R^2 + X^2}. \tag{10}$$

Neglecting the terms in brackets, which express the nonlinearity of the attenuator, we find from (5)

$$P_{H1} = \frac{E^2 R_H}{X_0}e^{-2\alpha l_1}. \tag{11}$$

By inserting (10) and (11) in (9) we obtain

$$A_0 = 10\log\frac{(X_0 e^{\alpha l_1})^2}{R^2 + X^2}. \tag{12}$$

Whence

$$|X_0 e^{\alpha l_1}| = 10^{0.05A_0}\sqrt{R^2 + X^2}. \tag{13}$$

By inserting (13) in (8) we obtain a formula which represents the nonlinearity of a cutoff attenuator:

$$\Delta = 4.34\left(\frac{1}{1+x^2}e^{-0.1A_0} + \frac{2x}{\sqrt{1+x^2}}10^{-0.05A_0}\right), \tag{14}$$

where

$$x = \frac{\dfrac{X}{X_0}}{\left|\dfrac{X}{X_0}\right|}\cdot\frac{|X|}{R}. \tag{15}$$

The first factor in the right-hand side of (15) determines the sign of x, which is positive if in the equivalent circuit shown in Fig. 1 the signs of X and X_0 are the same, and is negative if these signs are different.

Formula (14) and the curves in Fig. 3, which have been calculated from this formula, show that the nonlinearity of the cutoff attenuator is determined by its initial loss A_0, but it also depends on the impedance of the source and the load, connected to the attenuator.

In designing the attenuator one should always strive to attain the permissible nonlinearity at as small an initial loss as possible. It follows from (14) that for a given A_0 the nonlinearity will be at a minimum if the source and the load are purely resistive (x = 0), which confirms [1].

In this case

$$\Delta = 4.34 \cdot 10^{-0.1A_0}. \tag{16}$$

For instance, $|\Delta| \leq 0.01$ db is attained for $A_0 \geq 26$ db.

An adjustment of $x = 0$ can be attained in intermediate frequency attenuators, which are used in superheterodyne attenuation measuring circuits (for instance [2]). Such attenuators work at fixed frequencies. The exciting and receiving electrodes form part of the circuits attached to them, which can be tuned to resonance. However, an adjustment for $x = 0$ cannot be considered a sufficient guarantee for decreasing the nonlinearity of the attenuator, since even a small detuning will greatly increase the value of Δ. For instance, if $x = 0.1$, then $|\Delta| \leq 0.01$ db for $A_0 \geq 39$ db. For a detuning equal to the bandwidth of the circuit ($x = 1$) it is necessary to have $A_0 \geq 56$ db. Such a pronounced effect of the amount of detuning is due to the fact that factor $10^{-0.05A_0}$ of the second term in (14) decreases much more slowly than factor $10^{-0.1A_0}$ of the first term. Hence, for normal values of A_0 and a detuning which is not too small, nonlinearity is determined almost entirely by the second term. In UHF cutoff attenuators working over wide frequency bands relatively large values of $\underline{x}$ are inevitable. Hence, small values of Δ can be reliably obtained only by providing a sufficiently large initial attenuation (of the order of 40 db for $|\Delta| \leq 0.1$ db and 60 db for $|\Delta| \leq 0.01$ db).

It will be seen from (14) that it is theoretically possible to decrease nonlinearity by selecting the amount of detuning $\underline{x}$ so as to make the second term of the formula compensate the first. Such a partial compensation occurs particularly at $x < 0$. Hence, the nonlinearity of an attenuator for $x = -0.1$ is considerably smaller than for $x = +0.1$. However, in practice it is impossible to attain accurately given values of detuning, especially in wide-band instruments.

Let us note that the initial loss A_0 determined in (9) and used in all the subsequent formulas differs from the concept of the nominal initial loss A_{it} of an attenuator, which is widely used in UHF technology, and measured in a matched channel by inserting and withdrawing the attenuator. Normally A_{it} is slightly larger than A_0 (by an amount of the order of 3-10 db), especially when dissipating resistors used for matching are placed inside the attenuator (and this is often the case in UHF attenuators). The relation between A_{it} and A_0 can be approximately calculated for any particular attenuator circuit. It is therefore sufficient for determining A_0 to measure A_{it}. It is also possible to measure A_0 obtained from (9) directly, if the construction of the attenuator is such that a galvanic contact between the exciting and receiving electrodes is possible. The formulas for evaluating the nonlinearity of the attenuator are of an exploratory nature, and the value of A_0 need only be known approximately.

SUMMARY

1. The nonlinearity of a cutoff attenuator due to the loading effect is determined by the initial attenuator loss and depends to a great extent on the relation between the reactive and resistive components of the load and source impedances.

2. In wide-band cutoff attenuators the value of the load impedance reactive component is bound to be substantial. For such attenuators nonlinearity decreases proportionately to a decreasing field strength when the initial loss is increased. In order to attain a nonlinearity of $|\Delta| \leq 0.1$ db it is necessary to have an initial loss of $A_0 \geq 40$ db, and for $|\Delta| \leq 0.01$ db the loss should be $A_0 \geq 60$ db.

3. For attenuators working at a fixed frequency (for instance, intermediate frequency attenuators used in superheterodyne circuits for measuring attenuation), it is possible to reduce nonlinearity by a very precise tuning to resonance of the circuits connected to the exciting and receiving electrodes. In such attenuators nonlinearity decreases proportionately to the square of the output voltage when the initial loss is increased. In order to attain a nonlinearity of $|\Delta| \leq 0.01$ db it is necessary to have an initial loss of $A_0 \geq 26$ db.

4. The nonlinearity due to loading is considerable, and in many cases may predominate over the nonlinearity due to spurious types of waves.

LITERATURE CITED

1. Berlow and Cullen, Measurements at Superhigh Frequencies [Russian translation] ("Sovetskoe radio" Press, 1952).
2. L. A. Birger, Errors in Measuring Attenuation by Means of the Superheterodyne Method, Trudy VNIIFTRI No. 44 (10) (Moscow, 1960).

MATERIAL RECEIVED BY THE EDITORIAL BOARD

AN IMPORTANT SPHERE OF WORK
FROM THE EXPERIENCE OF THE KIEV STATE INSPECTION LABORATORY OF MEASURING EQUIPMENT

M. D. Kalennikov

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 52-53,
November, 1960

During the past two years great attention has been paid by the Committee of Standards, Measures and Measuring Instruments to problems of instrument-making. The recently issued regulation 2-59 simplifies considerably the procedure for testing instruments by the agencies of the Committee. The separation of the tested instruments into two groups consisting of experimental models and mass produced instruments has made it possible to produce without delays new, improved measuring instruments.

Some time ago the Committee requested the State Inspection Laboratories of Measuring Equipment radically to improve the control over instrument-making, strengthen the instrument-making personnel by the most highly qualified workers, actively assist in bringing into production new and withdrawing obsolete types of instruments, sharply increase the requirements with respect to the quality of the manufactured measuring equipment, etc.

The Kiev GKL (State Inspection Laboratory) has adopted certain measures which have helped to improve the quality of the manufactured instruments.

On the basis of a wide observation of the behavior of instruments in operation, numerous reports from the users of the instruments, check tests of instruments, etc., the laboratory, in conjunction with the instrument-making plants, has drawn up a plan which has been submitted for approval to the Sovnarkhoz (Council of National Economy) for introducing into production in 1960-1961 new and withdrawing obsolete types of instruments.

Recently the production of 23 obsolete types of instruments was discontinued in the Kiev plants and the production of 60 new or modernized models was assimilated.

In 1960-61 at the Kiev plants of the Sovnarkhoz 45 obsolete types of instruments will be withdrawn from production and replaced by new ones.

In the following eighteen months the instrument-making plants of Kiev will replace the production of 51 obsolete by 122 modernized instruments.

By the end of 1960 the "Tochélektropribor" plant will discontinue the production of grade 0.5 single-range voltmeters, ammeters and wattmeters types D-525, D-526 and D-527, replacing them by double-range grade 0.2 type D-566 instruments, which will be able to work at higher frequencies.

The Dzerzhinskii plant of rationing automatic devices will discontinue in the 4th quarter of 1960 the production of semiautomatic scales type DSP-100 for weighing sugar, semiautomatic equipment type DVM-100 for rationing flour by weight, and automatic scales type DU-200 for coal, and will replace them with modernized models, etc.

In order to improve the quality of the manufactured instruments the Kiev GKL has considerably raised the requirements in checking and state testing of instruments.

Periodic inspection testing of mass produced instruments is carried out as a rule twice a year for each type of instrument; the data on their operational properties are studied and now it is also estimated whether they meet the up-to-date requirements of the measurement technique and our national economy. This helps to a great extent in finding design and production defects in measures and measuring instruments as they are being produced.

Thus, of the 72 types of instruments inspected in the 2nd quarter of 1960, two types were withdrawn from production owing to serious defects. Five models were considered obsolete with respect to the modern state of the measuring technique.

The low quality of commercial automatic devices produced by the Kiev plant should be especially noted. An automatic device type AT-9M for selling wine and other liquids has been withdrawn from production from July 1, 1960, owing to serious design and production defects in its units and components and the absence of cooling. The factory must adopt decisive measures for ensuring faultless operation of automatic devices and improving their design. Yet the plant is behind schedule in the production of experimental batches of improved automatic devices type AT-51S for selling wine and other liquids, type AT-28M for selling vegetable oil in portions of 200 and 400 g, type AT-49 for selling pasteurized milk in portions of one glass, despite the fact that experimental models of all these devices have been tested out and approved for production by the Committee.

The Kiev plant KIP and some other factories are lagging in the production of improved models of instruments.

The Kiev GKL summarizes each quarter the data obtained from their periodic tests of instruments and sends the summary to the Sovnarkhoz (Council of National Economy) so that it can render the necessary assistance to the plants.

As a rule the Sovnarkhoz adopts concrete measures for improving the quality of the produced instruments.

In agreement with the Sovnarkhoz the GKL systematically holds conferences at the instrument-making plants of Kiev dealing with the results of its periodic testing of instruments.

The GKL also organizes conferences on the problems of designing new and modernizing obsolete instruments. These conferences are attended by representatives of the manufacturing plants and the user organizations.

As the results of the combined efforts of the Kiev GKL, the Sovnarkhoz and various plants, the quality of many instruments has improved.

For instance, the laboratory took considerable pains in order to improve the cable measuring instrument type KP-50. On the basis of laboratory tests and the suggestions of the GKL the plant developed a new instrument type PKP-2 which serves the same purpose but has an improved insulation measuring circuit, 30% smaller overall dimensions, etc. The laboratory workers have taken an active part in the development and production by the "Nefteizmeritel'" plant of a new gasoline pump type SD-100, which is highly productive in operation.

It is obvious that control of the production of modern high quality instruments is impossible without the active participation of the GKL experts.

The Kiev GKL organized for controlling instrument production a group of 8 engineers by freeing them from other responsibilities. The group tests instruments, studies their operational properties, makes suggestions for withdrawing from production obsolete and replacing them with new instruments, etc. The control of new production is engaging 25% of the total personnel of the Kiev GKL, including those dealing with the state testing of manufactured instruments. However, the rapid growth in the production of new instruments by the Kiev plants will necessitate in the near future an increase, by means of redistribution of work, in the staff dealing with the control of instrument-making factories.

WIDER PUBLICITY FOR THE PROBLEMS OF MEASUREMENT TECHNIQUES AND STANDARDIZATION

A. E. Karamov

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November, 1960

Following the decisions of the 21st Party Congress and the July plenary session of the CPSU Central Committee, which stressed the important role of effective publicity in the development of technical progress in our country, the Azerbaidzhan GKL (State Inspection Laboratory) has considerably intensified its publicity in the sphere of measurement techniques and standardization.

The laboratory personnel avails itself of every possible opportunity for informing the workers in the factories on new measurement techniques, their improved maintenance, the foremost experience gained in production control, production automation, etc.

This publicity is conducted by the engineers and technicians of the laboratory at the permanently running refresher courses organized for the service inspection personnel, and at conferences held at each plant after every heavy inspection of its measuring equipment, after checking its adherence to standards and specifications, and after giving technical advice.

The audiences are not very large but they consist of highly qualified experts in measurement techniques.

Striving to enlarge its audience, and bring to the notice of a wide circle of workers in industry, transport, building, and agriculture, the problems of measurement, the Azerbaidzhan GKL organized in the 2nd quarter of 1960 a radio broadcast on "correct organization of the measurement equipment inspection as an important condition of further industrial progress."

This talk dealt in detail with the importance of measurement equipment in present-day production, the necessity of inspecting this equipment, and with the procedure and organization of state and service inspection.

In order to increase the knowledge of school children in this sphere a broadcast on "measures and the metric system" was organized.

In order to interest youth in measurement techniques and standardization, the GKL established contact at the beginning of 1960 with the Young Communist organization of the republic. Two senior laboratory engineers were elected to the economic commission of the Azerbaidzhan Young Communist League Central Committee. The economic commission will coordinate the work of the Young Communist headquarters, posts, and mobile squads at the plants of the republic, exercise a methodical control over them, plan and direct their work.

The very first attempts of the joint work with the Young Communists have brought satisfactory results. Our laboratory in conjunction with the organization of the Azerbaidzhan Young Communist League Central Committee sent a team to the Baladzhany railroad tank-car steaming station in order to check the adherence to GOST (State standard) 1510-50. The data obtained in this inspection, which showed serious infringements of the GOST, short-comings in the accounting system and in planning the requirements and supplies of oil products, was published in the republican newspaper "Young Azerbaidzhan." Among other things this article raised the problem of organizing the control by Young Communists of the emptying of oil products from railroad tank-cars, which it is planned to exercise through consecutive control teams established at railroad stations.

Our laboratory published an article in the same paper on the tasks facing the economic commissions and teams at the plants in the sphere of supervising measurement equipment, and checking the adherence to standards and specifications.

The workers of the GKL will take part in the Young Communist mobile teams, advise the Young Communist members of these teams and commissions on the correct utilization of measuring devices, correct accounting in the use of fuel, water and electricity, and on problems of standardization. The Young Communist organizations will take certain enterprises under their wing and start controlling the adherence to state standards and the

work of the service inspection agencies in supervising the measuring equipment. They will check the execution by the plants of the suggestions made by the laboratory aimed at improving and raising the quality of production.

Joint work of the GKL and the Young Communist organizations of the republic will help to improve the supervision of the measurement equipment and achieve a strict adherence by the plants to the standards and specifications.

ORGANIZING THE PRODUCTION OF REFERENCE EQUIPMENT

V. A. Sergeev

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, p. 54,
November, 1960

Many engineering and instrument making plants possess a large quantity of linear and angle measuring instruments. The rising requirements with respect to the accuracy of the products lead to an increasing use in engineering of new measuring devices calibrated in microns and fractions of microns.

However, the technical perfection of a number of special reference devices and the existing methods of checking lag considerably behind the requirements of up-to-date production. For instance, side by side with special reference instruments completely adequate with respect to their accuracy and productivity in determining errors of indicating devices used at the "Krasnyi Instrumental'shchik" plant, the majority of engineering factories use for this purpose simplified and nonproductive equipment made at their own plants.

The same condition exists with respect to checking many other types of measuring instruments.

Many plants use instruments without universal adjustments or measuring devices of a simplified design without mechanization. Thus, caliper gauges are supposed to be checked every day when they are returned to the stores, but they are checked, in the absence of other means, against block gauges, which is extremely nonproductive and does not take into account deformations in the calipers.

The use made by various plants of simplified and nonproductive testing methods is due to the lack of fully adequate 2nd grade reference instruments and the lack of any information on new, modern techniques in literature.

The Bureau of Interchangeability, which started developing new reference instruments, has discontinued this work.

No provision for new reference instruments in the standardization of measuring equipment for checking linear and angle dimensions is made by the Interchangeability Bureau in its plans for 1959-1965.

Such data are also lacking from the information leaflet No. 341-LI-37 entitled "List of Equipment for Measuring Lengths and Angles Recommended for Use in Engineering Plants," issued by the department of linear and angular measurements of the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures and Measuring Instruments).

It is only very seldom that our scientific and technical periodicals deal with the experience gained by our plants in producing and applying special reference equipment.

Obsolete equipment leads not only to large unproductive expenditure on checking operations, but also often to erroneous test results.

Taking into consideration the large volume of work involved in supervising the equipment for measuring lengths and angles, it would appear expedient for the State Committee on Automation in Engineering attached

to the Council of Ministers of the USSR, in conjunction with VNIIK, to investigate the degree to which the equipment used in engineering for checking instruments employed in mass production measurements of lengths and angles is lagging behind modern technical requirements, and to set up a basic standard and technical targets for developing special reference instruments used in checking measuring equipment; and to instruct the Bureau of Interchangeability and appropriate design offices to develop most accurate and productive reference instruments.

This would make it possible to organize in instrument-making plants mass production of equipment for commercial metrological purposes, whose application would undoubtedly result in considerable savings and help to raise the quality of production.

ESSAYS AND REVIEWS

ELECTRICAL INSTRUMENT-MAKING IN HOLLAND

K. K. Ilyunin and A. F. Gorodovskii

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 55-56,
November, 1960

The instrument-making industry of Holland started developing in the main only in recent years. That is the reason why the electrical instruments produced by Dutch industry can compete on the international market with the instruments of the most advanced capitalist countries.

Below we enumerate some of the largest instrument-making firms in Holland.

The firm Nieaf produces in the main electrical measuring instruments. The firm Kipp produces various types of galvanometers, thermal instruments, high pressure equipment, optical instruments, pyrometers, recording instruments, medical instruments, etc. The firm Electrofakt produces various pH-measuring and electronic instruments. The firm Piikel manufactures electronic instruments and equipment and megohmmeters, ohmmeters, electronic voltmeters, quartz-crystal oscillators, frequency-meters, etc. The firm Ekaf manufactures stabilizers and various electronic devices. And the firm Evershed is engaged in the production of automatic control and thermotechnical equipment.

Very few resistance or impedance measuring instruments are produced in Holland, and the list of recording instruments is limited to a few types.

The electrical instrument measuring industry specializes mostly in electrical rack-mounted pointer instruments.

Thus the firm Nieaf produces 478 types (without taking into consideration the difference in scales) of electrical rack-mounted pointer measuring instruments (in external appearance and container design 12 types, and 44 types differing in dimensions).

This firm produces instruments in round and rectangular as well as shaped cases; it makes gas-explosion-proof, shockproof and other instruments.

Its highly sensitive moving coil instruments are made, as a rule, with permanent magnets which do not demagnetize when the magnetic circuit is dismantled and have elongated coils with their axes mounted on bearings.

A schematic layout of such a mechanism is given in Fig. 1. The coil with its yoke is easily detachable from the magnetic system without dismantling or demagnetizing the latter. The angle of rotation of the coil can exceed 90°.

Instruments are also produced with the magnets placed inside the coils (Fig. 2).

For extending the measuring limits the normal multiplying resistors and shunts are used; the latter are made up to 40,000 amp with a drop of 100 mv across the shunt. These shunts are made of rod manganin. Special shunts are also produced with a voltage drop of 1,000 mv across them. The grade of instruments is 1.5 and that of the shunts 0.5.

The design of moving iron, electrodynamic, ferrodynamic and other types of instruments is similar to corresponding generally adopted designs.

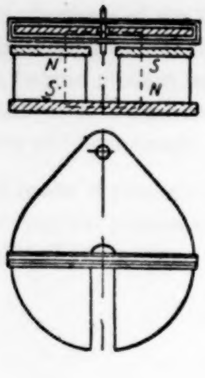

Fig. 1.

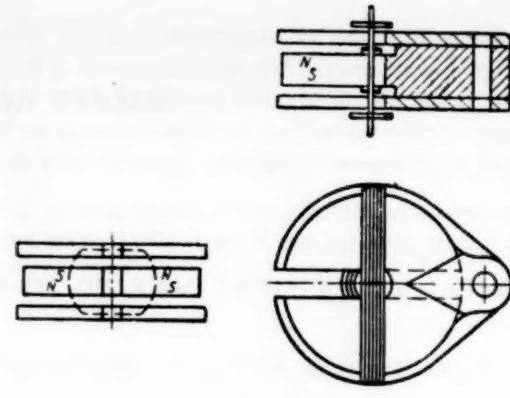

Fig. 2.

Fig. 3.

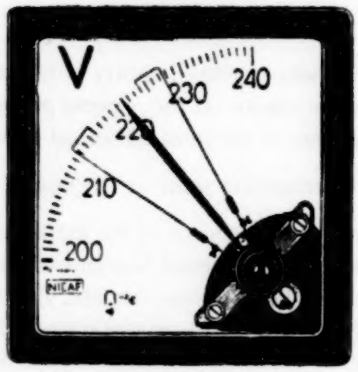

Fig. 4.

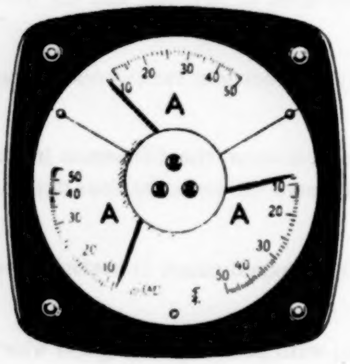

Fig. 5.

Side by side with air, induction damping is used; the latter is usually attained by means of a vane in the shape of a circular disk fixed to the spindle of the moving system. The disk passes in a gap between two miniature cylindrical magnets.

Among the various types of instruments attention should be drawn to a series of rack-mounted frequency meters of various systems, including detector-type instruments with a range of 0 to 1,000 cps; ferrodynamic instruments with a range of 50 to 70 cps; vibration-type instruments with a range of 45 to 55 cps, etc.

Bimetallic rack-mounted ammeters are usually made for signaling purposes with an additional adjustable control pointer or signaling contacts.

A well-designed scale is supplied with circular-dial moving-coil suppressed-zero instruments (Fig. 3), as well as with rack-mounted detector-type grade 0.5 instruments (Fig. 4); the latter have built-in signaling contacts and a separate relay attachment.

The firm Nieaf manufactures combined rack-mounted instruments which include in a single case three ammeters (Fig. 5), synchronizing units (Fig. 6), etc., as well as various portable pointer instruments starting with grade 0.2, slidewire and cable bridges, megohmmeters and multirange instruments.

A universal grade 2.5 multirange pointer instrument "Polymeter-B" (Fig. 7) has 31 ranges on 5 scales; the dc ranges cover measurements from 50 μa to 10 amp and from 100 mv to 5,000 v; resistance is measured from

Fig. 6.

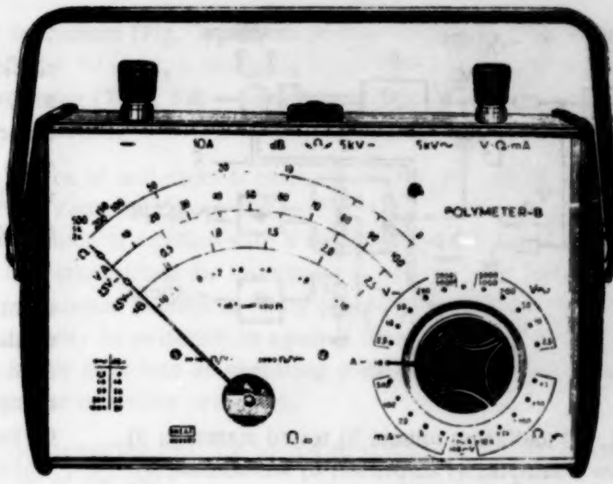

Fig. 7.

2 kilohm to 20 meg; ac ranges cover from 500 μa to 10 amp and from 2.5 to 5,000 v. The instrument's sensitivity on dc is 20,000 ohm/v and on ac 2,000 ohm/v. The length of the middle scale is 105 mm. It uses germanium rectifiers and a measuring coil on bearings (50 μa, 50 mv). The ohmmeter is supplied from a built-in battery of 24 v with a tap at 1.5 v. Its dimensions are (without the carrying case) 200 × 125 × 75 mm, and its weight is 1.1 kg.

The same firm produces rack-mounted instruments for recording on a rectangular coordinate chart and using ribbon-type rectifiers.

The use of ribbon-type rectifiers makes it possible to reduce the size of the instrument and decrease the number of bearing contacts as compared with the rocker-type instrument.

SUMMARY

We should organize and develop the production of electrical measuring instruments similar to those made by Dutch firms, such as rack-mounted indicating instruments of a nominal grade of 0.5 (and higher) and scale angles of 90 and 240°; rack-mounted bimetallic pointer instruments (these instruments have been developed by the Kiev Polytechnic Institute); rack-mounted pointer instruments with built-in control and signaling contacts used for many automatic and semiautomatic processes.

INSTRUMENT FOR MEASURING THE THICKNESS OF TAPES AND FOILS*

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 57-59, November, 1960

The national plant of K. Zeiss (G. D. R.) has developed and is producing a new instrument for contactless measurement of the thickness of tapes and foils in the process of their manufacture. Measurements are made by means of beta-radiations of radioactive sources.

* Report of an article written by W. Schnabl and F. Söldner, "Registriendes Flächengewichtsmessgerät," Jenaer Rundschau, V. E. B. K. Zeiss, Messe-Sonderheft, 1960.

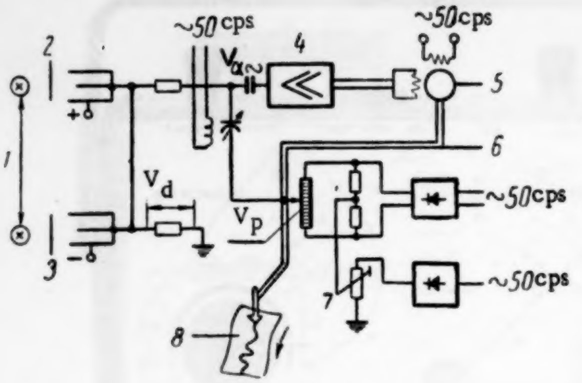

Fig. 1. 1) Radiation source; 2) tested material; 3) reference sample; 4) amplifier; 5) servomotor; 6) mechanical drive; 7) zero setting; 8) pen.

The physical basis of the methods for measuring thickness by means of beta-radiations is well known and, therefore, we need only mention that beta-ray absorption follows an exponential law whose parameters are determined by the ordinal number and atomic weight of the absorbing material, as well as by the energy of the radiation used.

Figure 1 shows the schematic of the above instrument which operates on the basis of a compensation method and a differential circuit, in which the measured material is placed in one ionization chamber and compared with the sample placed in the other chamber. Owing to the use of two chambers the variations in the ambient air temperature and pressure do not affect measurements, providing these two variables are maintained equal to each other inside the two chambers.

The two chambers are connected in such a manner that the voltage across the load resistor R_a is equal to zero when the absorption of radiation by the two samples is the same.

If the thicknesses of the tested and reference samples differ, the difference voltage V_d produced across the load resistor is fed to a vibrating capacitor transducer, which operates from the 50 cps mains and transforms the dc difference voltage into an ac voltage. The ac voltage thus obtained is amplified by a highly stable ac amplifier and fed to a phase-sensitive servomotor. This motor drives the slides of a potentiometer. The dc voltage V_p across the potentiometer is used to compensate the dc voltage across the vibrating capacitor, thus making the ac amplifier operate as a null-indicator.

The potentiometer slider is connected to a device which continuously records the readings.

The servomotor is sufficiently powerful to drive an automatic regulator for remote recording, etc.

The above differential system of measurements requires two sources of radiation. However, the decay of the radiation sources affects the accuracy of measurements to a considerably smaller extent than in a direct measuring circuit, in which the required thickness is determined only by the beta-ray absorption in a single measured sample.

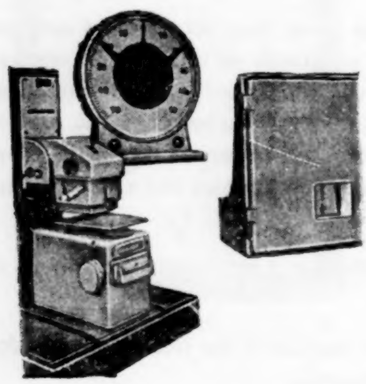

Fig. 2.

Fig. 3.

The experience gained during several decades by the national plant of K. Zeiss in producing precision measuring equipment was effectively used in the design of this instrument. Owing to this fact and the use of a differential circuit the above instrument meets all the basic requirements of industry, including the protection of the operating personnel from the harmful effects of beta-radiation, the accuracy and range of measurements, the sensitivity and stability of readings, the facilities for remote measurements and connection to automatic systems for controlling machines or production processes, a reliable design, ease of operation, and stability with respect to kinematic effects.

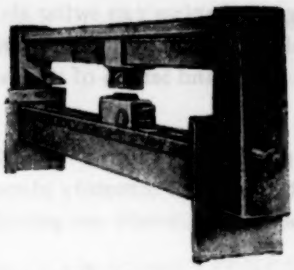

Fig. 4.

The instrument (Fig. 2) consists of four basic units, the source of radiations (140 × 190 × 80 mm), a receiving head (370 × 270 × 200 mm), an amplifier with a recorder (730 × 810 × 390 mm), and an indicating instrument (550 mm in diameter).

The source of radiations is placed 50-80 mm above the measuring chamber, and it contains isotope Sr^{90} or Tl^{204} with an activity of about 20 mC. The radiation source is supplied with a signaling lamp which lights when the source is in operation; when the instrument is switched off the chamber containing the preparation is automatically placed in a protected condition. The instrument can only be switched on again if the chamber with the preparation is again placed by hand into an operating position. This serves as a safety precaution for the operating personnel.

Figure 2 shows the instrument designed for measuring foil; the source of radiations can be withdrawn to one side in order not to interfere with the placing of the foil.

The receiving head contains both the ionization chambers 90 mm in diameter and 100 mm high. The windows intended for the passing of the rays are covered with aluminum foil and protected by steel grating; they are also supplied with special compressed-air blow-out devices which provide a speedy cleaning of the windows, which is very necessary when the instruments are used in industry premises. Inside the head the air has a low humidity content owing to the use of dessicants.

The parameters of the vibrating capacitor with a high resistor make their use possible in other spheres of measurements. It has highly stable contact potentials. Owing to the built-in drying agents its insulation is high enough even in very damp ambient air.

Figure 3 shows the main amplifier. Its entire electrical circuit is placed inside a hermetically sealed aluminum body. The experience gained in using other instruments under commercial climatic conditions has shown that only a tightly-sealed container, similar to that supplied in this instrument, meets the desirable high requirements. Dust with grains of 1-2 μ penetrates the tiniest cracks, making careful sealing of the container necessary. The same applies to the penetration of corrosive gases or vapors. In order to prevent the corrosion of amplifier components dessicants are used and for the worst conditions forced ventilation by clean air. This is especially important for operation in chemical plants.

The tube amplifier, recorder, automatic potentiometer and servomotor are mounted on brackets which can be withdrawn from the main cabinet. This arrangement and the layout of the amplifier make it easily accessible during operation. In conformity with safety regulations these brackets can only be withdrawn by means of special tools.

The compensation method of measurement makes the use of a relatively simple amplifier possible. The instrument uses a precision automatic potentiometer made by the national plant of K. Zeiss. The instrument is also provided with a transmitting selsyn for a remote measuring system and a second potentiometer for regulating an automatic control system (feeding rollers, containing a hoist, measuring out and supplying materials, etc.). By adjusting the selsyn, the zero reading of the remote measuring system can be given any required value. The main amplifier is supplied with a stepped switch for adjusting the sensitivity of the instrument.

For strip rolling mills, paper making machines and the production of plastics a large-scale indicating instrument, whose readings can be seen from a considerable distance, is used with a scale which has a zero reading in its center and two adjustable markers to each side of it for showing the tolerances in the thickness of the measured materials. Should a tolerance be exceeded a visual or sound alarm is immediately connected. Such an arrangement is necessary for the paper-making industry, since if the tolerances are exceeded or a tape broken immediate steps must be taken to remedy the defects. The large indicating instrument, the same as all the other units, is hermetically sealed.

For measuring thicknesses of paper and plastic materials of a width of 1 to 6 m the instrument is supplied with a special scanning mechanism (Fig. 4). The receiving head is placed on rollers along a channel guiding rail, while the source of radiation moves synchronously with the head along a similar guiding rail. Both the head and the source are propelled by means of steel wires and a friction drive. The electrical leads and

compressed air pipes are placed inside the hollow runners. The whole scanning mechanism can swing about its two journals, and be placed in a position for measuring vertically propelled strips. For the purpose of controlling the measuring device and setting it in the required position with respect to the width and length of the measured tape, a special control cabinet is provided.

The basic data of the instrument are: measuring range of 30-1,000 g/m^2; measuring error of 0.1-1%; time constant of 1 sec; heating up time not exceeding 10 min. Readings are taken by means of remotely placed direct-reading instruments; recordings are made by means of an electromechanical recorder. Circuits are provided for an automatic regulator and for signaling the breaking of a tape.

The sensitivity of the instrument can be changed in steps by varying the compensation voltage. At the maximum sensitivity the variation of the measured weight per area by 1% produces a deflection of 5 mm in the position of the recorded line on the chart. Such a sensitivity is considerably higher than that required in the majority of practical cases.

The supply voltage variations only affect the minimum sensitivity of the amplifier, which is not important since this sensitivity has been selected with an ample margin. Tests showed that supply voltage variations of ± 10% have no noticeable effect on the instrument readings; similarly, large supply voltage variations have not affected the zero setting during 8 hours of testing.

Tests have also shown that the instrument set to its highest sensitivity, and connected to the mains in a completely cold state, is ready for operation in 5-10 minutes.

The instrument can be recommended for use in the paper industry, in the production of artificial materials, compressed wood sheets, cinema films and foils made of different materials. Its use will help to decrease rejects, reduce expenditure on raw materials and ensure the correct weight per area in the manufactured tapes or foils.

According to published data, contactless measuring instruments of the same standard as the Zeiss instrument and designed for measuring the thickness of tapes and foils, provide a saving, when used with an average paper-making machine, of 100-200 tons of raw materials per year, and when used in the production of artificial leather and oilcloth, a saving of up to 2 kg of polyvinyl chloride per 100 m^2. In the production of cinefilms the price of one measuring equipment pays for itself in one year. It is very important for the electrical industry to be able to reduce the tolerances on paper and metal foil, in order to reduce considerably (13%) the size of capacitors.

The use of this and similar instruments will, of course, require the adherence to all the compulsory safety measures specified for work with beta-radiations.

INFORMATION

REPUBLICAN CONFERENCE ON CONTROLLING THE QUALITY OF MANUFACTURED INSTRUMENTS

B. L. Sokolov

Translated from Izmeritel'naya Tekhnika, 1960, No. 11, pp. 59-62, November, 1960

In putting into effect the decision of the July Plenary Session of the CPSU Central Committee, the administration of the RSFSR Council of Ministers' Plenipotentiary Committee organized in September, 1960, republican conferences of the heads of state inspection laboratories of measuring equipment on whose territory there are instrument-making plants, and of heads of the State Inspection Laboratory (GKL) Control and Checking Stations (KPP) at these plants. The object of the conference was to exchange experience in controlling the quality of measures and measuring instruments manufactured in the RSFSR (Russian Socialist Federated Soviet Republic), and to discuss a further increase in the efficiency of instrument-making plants.

The conference was preceded by visits of the Administration Representatives to certain GKLs, instrument-making plants and Sovnarkhozes (Councils of National Economy), in order to ascertain on the spot whether the instruments are up to the required quality and meet the requirements of modern technology, and to check up on measures undertaken by the GKL plants for modernizing the instruments now in production.

Reports were presented to the conference by the heads of several state inspection laboratories: by S. A. Zabutov from Krasnodar, by P. M. Larionov from Chelyabinsk, by Kh. D. Valeev from the Tatar Republic, by B. Yu. Rozin from Omsk, by D. I. Shmatok from Tomsk and by B. L. Sokolov, the chief engineer of the Administration.

In their reports the heads of the GKLs described the condition of the instrument-making industry on the territories covered by their laboratories, the work of their GKLs and KPPs at the instrument-making plants, and the measures undertaken by them to improve this work and to assimilate new measuring equipment according to the decision of the July plenary session of the CPSU Central Committee. The speakers also dealt with the relations between the GKLs and the Sovnarkhozes and the participation of the KPPs and GKLs in various factory commissions and conferences on improving the quality of instruments and assimilating new measuring equipment.

S. A. Zabutov showed by several examples the increased productivity of labor in checking new instruments, attained by the KPPs as a result of applying various rationalization proposals made by the KPP workers Coms. Lunev, Maslov, Ustimenko and others.

The KPP of the Krasnodar GKL has a wide experience in periodic testing of instruments, since it carries out 180 such tests a year. The speaker showed how useful these tests were and the proposals made as the result of them to the tested plants for improving the quality of production. The report also noted such deficiencies as a superficial attitude toward certain periodic tests, checking the specified methods in producing instruments, checking the condition of the production equipment, checking the work of auxiliary shops and plants which must supply the main plant with high quality materials and semi-manufactured articles.

The report criticized the Kokchetav mechanical plant which supplied low quality dial heads.

In conclusion the speaker expressed certain grievances with respect to the Committee, which makes decisions regarding the treatment of plants without consulting the GKL.

P. M. Larionov reported that the instruments manufactured in his region have successfully passed state testing, and that the plants do not produce instruments which have not been approved by the committee. The speaker mainly dealt with control in instrument production in the light of the decisions of the July plenary session of the CPSU Central Committee. The GKL insisted that the Sovnarkhoz should and did organize quality inspection, and the laboratory is establishing close relations with the Sovnarkhoz technical department. Certain workers of the GKL are allocated to definite plants for training workers at the plants.

The GKL has also established close relations with the research institutes and design offices in the region which are engaged in developing new measures and measuring instruments.

The speaker reported on the work carried out by the GKL for modernizing the instruments in production and on the measures taken by the GKL for studying the operational properties of the instruments manufactured in the Chelyabinsk region, and for eliminating the deficiencies thus found.

B. Yu. Rozin reported that the GKL personnel, having studied the July decisions of the plenary session of the CPSU Central Committee, mapped out the organizational and technical measures for improving the control over the quality of the manufactured instruments. The speaker also noted the important work carried out by the GKL for improving the quality of production and modernization of instruments and the development of new designs. The GKL systematically uses the reports received from the customers on the quality of the purchased instruments, and studies the complaints received by the factories. The reasons for rejecting instruments in periodic and snap tests are studied, and measures are taken in conjunction with the manufacturing plant to avoid in future the causes of these defects.

The report noted the poor quality of enameled wire supplied by the plants of the Moscow regional and Tomsk Sovnarkhozes, and at the same time pointed out the necessity of specifying more clearly certain requirements set out in the standard for enameled wire.

The speaker requested the Committee to establish a procedure by which the plants seeking permission to manufacture measures or measuring instruments should apply to the Committee only through the GKLs, thus keeping the latter constantly informed on this question and making their opinion on the plant's request available to the Committee, since it may be useful when the latter considers the request.

In their reports Kh. D. Valeev and D. I. Shmatok dealt with the measures aimed at improving the quality of production in the Kazan' "Teplokontrol'" Plant and the Tomsk manometer plant, which are continuing to produce instruments of a low quality which do not meet the requirements of our national economy.

B. L. Sokolov noted the considerable development of instrument-making on the territory of the RSFSR while the manufacture of the simplest instruments in small badly equipped plants had been discontinued and the production of complex instruments in large plants either recently constructed or still under construction is being organized. New instruments are now being produced in regions where in the past there was no instrument-making industry at all. In 1961 alone the RSFSR plants will start production of 250 new measures and instruments, modernize the production of some 50 old types and discontinue the production of some 100 obsolete measures and instruments.

Periodic testing and studying of the operational properties of instruments manufactured in the RSFSR show that the quality of many of them has not yet reached the desirable high level, and certain GKLs, for instance, the Tatar, Gor'kii, Tambov, Tomsk, Kemerovo and other GKLs, have many failings and defects in their joint work with the instrument-making plants. In many instances heads of the GKLs do not take part in solving the problems connected with instrument-making plants and prefer the factories dealing directly with the Committee or the institutes which carry out state testing of the instruments.

The speaker drew the attention of the conference to the existence of serious defects in the manner in which many plants compile technical information on measuring instruments, which is often incomplete and does not take account of the new developments in the sphere of measurements.

Despite the fact that the study of the operational properties of instruments plays an important part in discovering their defects and their quality, there are still a few GKLs, for instance the Tatar GKL, which are not engaged in this useful work, and yet other GKLs conduct this work in a haphazard and formal manner. Another important reason which prevents the improvement in the quality of measuring instruments is the unsatisfactory way in which the instrument-making plants study the operational properties of the instruments, and the GKLs must devote their attention to organizing this work in the plants.

By pointing to certain outstanding examples the speaker showed that certain GKLs do not fully understand their role in helping to speed up the development and production by the instrument-making plants of new measuring equipment, and being engrossed in details they do not see the necessity of implementing important basic decisions.

Certain heads of GKLs were severely critized in this report, especially Com. Arutyunyan, the head of the Tambov GKL, who paid insufficient attention to the work of the KPPs at the instrument-making plants; examples of such an irresponsible attitude and the resultant deterioration in the quality of production were cited.

The report noted the necessity of improving considerably the training of GKL workers, and exchanging the experience acquired by various GKLs. The report also stressed the importance of checking the fulfilment of the suggestions made to the plants by the GKLs after inspections.

The attention of the conference was also drawn to such impermissible conditions as the existence and use in instrument-making plants of inaccurate, defective and untested measuring equipment, including that used in finishing operations.

In conclusion the speaker noted the important role played by the Sovnarkhozes in helping to eliminate defects in the instrument-making industry, and in this connection the part the GKLs should play in making businesslike suggestions to the Sovnarkhozes.

Many delegates took part in the discussion which followed the reports. The head of the Kursk GKL Com. Staroverov drew the attention of the conference to the fact that the quality of the dial heads for scales produced by the Kokchetav plant is completely unsatisfactory, and the users of the scales are obliged to replace the dials by beam pointers, i.e., return to the old design.

The head of the Ivanovo GKL Com. Solov'ev said that in a number of instances, in order to improve the quality of production, the GKL checked the efficiency of inspection between the various production stages. Thus, at one plant a large amount of rejects was found to be due to unsatisfactory heat treatment. The GKL established that the reason for these rejects was the incorrect operation of the instruments checking and controlling the heating temperature.

The GKLs in conjunction with the instrument-making plants have developed and introduced plans for designing and manufacturing new measuring instrument models, modernizing the existing production and discontinuing the production of obsolete instruments, replacing them by up-to-date designs.

Com. Furmavnina, head of the Tatar GKL's KPP at the "Teplokontrol' " plant noted that the instruments are submitted for checking irregularly, mainly in the last week of the month. The technical control division (OTK) does not fulfill its functions which, in fact, are performed by the instrument testers, who pay insufficient attention to checking the instruments before they are presented to the state inspector, who is therefore obliged to scrap many instruments. At the same time the conditions of work of state inspectors are far below those specified by the Committee. At this plant the KPP is not supplied with separate premises for checking, and no testing instruments are allocated to it, and the checking of the instruments has to be carried out at the adjustors' work-benches. This circumstance makes it impossible for the KPP workers to maintain the reference instruments at the required level of efficiency; each day much time has to be spent in adjusting the reference instruments at each work-bench before starting state checking.

Com. Furmavnina also described certain positive measures directed to the improvement of the production quality: the technical specification charts for all the main types of instruments have been revised and corrected and many procedures have been altered, taking into account the raised requirements for a higher quality of production; new equipment has been designed and made; an outside inspection group has been formed which studies the operational properties of the instruments and deals with other questions connected with the improvement of the production quality.

The head of the Kirov GKL, Com. Kraev, related his experience in organizing a conference for improving the quality of instruments, which was held with the participation of representatives from other plants. He also described the "control dismantling" of instruments, which helps to raise their quality. As a result of it, only 21 complaints about instruments were received in 1960, whereas in 1956 there were 933 and in 1959 48 complaints. Comrade Kraev suggested that the Committee should issue index-cards with concise information on

all the newly-adopted instruments, and that such cards, which should give brief technical characteristics of the instruments, the manufacturer's address and other data, be despatched to the GKLs.

Com. Malinin of the Gor'kii GKL proposed that the Committee should exert its influence on the choice of specialization for instrument-making plants and on decisions to transfer the production of instruments from a plant where it was well organized to another one which, in connection with this transfer, would encounter considerable difficulties in organizing production and maintaining its quality.

The head of the Kaluga GKL Com. Klochkov noted the unsatisfactory condition when the State Planning Committee decides on the production of instruments while the plant has not even had time to acquaint itself with the design of the instruments. He also drew the attention of the conference to the fact that there are instances when the production of instruments is transferred from one plant to another which is not in a position to start their manufacture.

The assistant head of the Measuring Instruments Administration of the Committee, Com. Zaks, noted that the development of instrument-making requires improved supervision by the GKLs and the Committee's institutes of the manufacture of instruments. This supervision should aim at raising the quality of instruments and continuously improving their design. Com. Zaks explained certain basic regulations underlying state and periodic testing of instruments, and drew the attention of the conference to the necessity for studying the operational properties of instruments during their periodic testing, and to the need for the designers of instruments, their users and the institutes to assist in the periodic testing of instruments.

The following comrades took part in the discussion: Ivanov, from the Bashkir GKL; Efremov, from the Saratov GKL; Arutyunyan, from the Tambov GKL; Samodurov, from the Ryazan' GKL; Puzenko from the Kemerovo GKL; Toropov, from the Vologda GKL, and Karlov from the Orel GKL, as well as Com. Gol'dshtein from the VNIIK (All-Union Scientific Research Institute of the Committee for Standards, Measures and Measuring Instruments).

The conference adopted an extensive resolution, directing all the GKL workers to concentrate their attention on fulfilling the tasks resulting from the decisions of the 21st CPSU Congress, and the July plenary session of the CPSU Central Committee on raising the quality and technical level of the measures and instruments produced in the RSFSR, on the assimilation by the industry of the latest achievements of measurement techniques, and on replacing measures and measuring instruments of obsolete design.

CONFERENCE ON INSTRUMENTS USING TORSION SUSPENSIONS

A. M. Lyubarskaya

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In Leningrad in October 1960 the first scientific and technical conference was held on the results of the work carried out by the "Vibrator" plant in designing and producing electrical measuring instruments using suspensions.

The work on applying torsion suspensions in electrical measuring instruments is of considerable importance. This work provides a new approach to important problems in instrument-making, raising the sensitivity, life, shock and vibration resistance, stability of readings and economy in use of the instruments.

The conference aroused considerable interest and representatives of 84 organizations from 9 cities in the USSR took part in it.

The present state, possibilities and trends in the future development of electrical measuring instruments using torsion suspensions were dealt with in the report of the "Vibrator" plant director A. M. Damskii.

Z. A. Timofeeva reported on new materials for suspensions and on the results of investigations of the physico-mechanical properties of suspension carried out according to GOST (State Standard) 9444-60. She also reported on the work of the plant in investigating and improving the construction of the suspension fastening and tension springs for instruments of various types.

P. I. Khrenkov reported on a new highly-productive precision machine tool for making suspensions.

Certain conclusions arrived at on the basis of the "Vibrator" plant's application of suspensions to vibration and shockproof instruments and oscillographs (loop and coil galvanometers) were dealt with by I. I. Rozenbaum and L. N. Gural'nik.

The result of the work conducted by the VNIIÉP (All-Union Scientific Research Institute of Electrical Instruments) under the direction of L. A. Savateev in studying the behavior of instruments with torsion suspensions under the effect of vibrations was reported by V. A. Zakharova and O. S. Lisovskaya.

The experience of a conveyor-belt assembly of these instruments, an analysis of their properties and means of improving their packing on delivery were dealt with by B. A. Cherkasskaya, V. A. Zel'dich and N. V. Korsakova.

Chief engineer of the "Vibrator" plant V. N. Smirnov examined the problem of standardizing the suspensions and organizing their centralized mass production, and also the problem of mass production of instruments using these suspensions.

L. Ya. Averbukh acquainted the conference with the proposed standard for the suspension-fixing components.

The delegates at the conference were given a description of the new instruments on suspensions developed by the "Vibrator" plant in the last few years. This question was dealt with in the papers read by V. I. Chervyakova on new laboratory thermal instruments with improved metrological and operational parameters; by Yu. K. Obram, on high precision laboratory instruments (grade 0.1 and 0.2); by S. G. Rabinovich on photoamplifiers with torsion suspension galvanometers, and by E. A. Levina on rack-mounted miniature highly sensitive suspension-type instruments.

In her report A. M. Lyubarskaya dealt with the results of state testing of measuring instruments using torsion suspensions and drew the attention of the conference to the situation that at present the design of instruments with torsion suspensions is mainly based on experimental results, without a mathematical basis for selecting the optimum materials and configurations for the suspensions. This fact was brought to the notice of the conference by other delegates as well. In this connection the papers read by P. B. Usatin on the methods of designing suspension-type instruments and by S. M. Pigin on the selection of the length of suspension were of particular interest. These papers were aimed at establishing methods of design computations for instruments whose mobile part is fixed on torsion suspensions.

The head of the OKB (Special Design Office) of the "Vibrator" plant B. A. Seliber summarized the work of the conference and formulated the basic problems whose solution is necessary in order to organize mass production of electrical measuring instruments using torsion suspensions.

E. S. Borisevich, Ya. S. Averbukh, V. A. Sol'ts, A. G. Kotova and others took part in the general discussion.

In its resolution the conference noted the positive experience gained by the "Vibrator" plant in developing torsion suspensions, and approved the initiative of the plant in calling this conference. Considering the speedy introduction of torsion suspensions in electrical measuring instruments necessary, the conference proposed that the interested manufacturing plants speed up the assimilation of torsion suspensions for measuring instruments.

The conference decided to request the superior organizations to organize a centralized production of standardized units for instruments with torsion suspensions, and to instruct the VNIIÉP to produce in the near future in conjunction with electrical instrument-making plants specifications for selecting the basic parameters for suspension-type instruments by means of design computation, including instruments operating in a dynamic condition, and to complete the work in standardizing the fixing of suspensions.

The conference requested the VNIIÉP to prepare and organize, together with the chief designers of the electrical instrument-making plants, a conference on the most important problems in developing electrical instrument-making.

Decisions were also arrived at on other organizational problems.

JAPANESE INDUSTRIAL EXHIBITION IN MOSCOW

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A Japanese industrial exhibition was held in Moscow from August 16 to September 4, 1960.

Among the exhibits an important place was reserved for instruments and equipment used in measuring the structure and property of metals and checking the quality of finished articles in metallurgy.

The Electron Optic Laboratory Company Limited exhibited an electronic magnetic-resonance spectrometer type MRH-3 for studying the structure of various substances by means of analyzing the spectrum of absorption lines and its relative intensity.

The resolution of the MRH-3 instrument is better than 10^{-8}, its resonance frequency is 40 Mc, and its maximum magnetic induction 10,000 gauss.

The same firm exhibited an electron microscope type JEM-6A capable of observing and recording on a film structural variations in metal when passing from elastic to plastic deformations, right up to the destruction of the samples. A special device makes it possible to study the behavior of metal under a common effect of load and temperature, both for a rising and falling value of the latter.

The resolution of the JEM-6A instrument is 8 A (guaranteed 12 A), its magnification is 600-200,000 diameters, photographic magnification up to 1,000,000 diameters, the temperature range used in measurements from − 140 to +1000°C, and the speed of filming of 1-6 frames per second.

The electron microscope of the Hitachi firm type HS-6 has a resolution of 25 A, an electron magnification of 2,000 to 20,000 diameters, and a photographic attachment which provides 36 photographs without reloading.

The firm Tokyo Keiki Seizosho Limited exhibited an ultrasonic flaw detector for checking the quality of metal products. Its frequency range is 0.5, 2, 2.25, 5 and 10 Mc. Its depth of detection for steel and aluminum is about 91 cm.

The Riken Keiki Fine Instrument Company exhibited portable gas analyzers which determine with speed and accuracy the presence in the air of CH_4 and CO_2, minute traces of benzine vapors and several other gases. The measurement error of gas analyzer A18 is ± 0.02%, and its range of measured gas concentrations is 0-10%; the measurement error of gas analyzer A21 is ±0.005%, and its range of measured gas concentration is 0-3%.

This firm also exhibited a "Riken" indicator type 10L-A for checking the purity of nitrogen in power transformers (limit of the measured concentration of oxygen is 0-20%, the error of readings ±0.2%) and instrument type 10L-V for checking the purity of hydrogen used for cooling electrical generators (the limit of the measured carbon dioxide concentration in air is 0-5% and the error of measurement ±0.1%).

The firm Kett exhibited hydrometers of various types for measuring moisture content of grain and timber, with a range of 10-20% moisture content for grain and 7-35% for timber; its error of measurement is ±0.5%.

Instruments for linear measurements made by the Tokyo Seimitsu Kogu Company Limited consist of various pneumatic and electrical measuring heads, used for linear measurements in devices for automatic checking of detail dimensions during machining and for sorting out by size finished products. Their measurement error is 0.5 μ and the measuring range is 10 to 2,000 μ.

Of the electrical measuring instruments the following should be noted.

The Sanyo Instruments Company Limited manufactures miniature moving coil (loop) oscillographs (6 vibrators) type 100A and 100B (12 vibrators).

The same firm exhibited universal amplifiers of various types for strain-gauge transducers (for instance, a six-channel amplifier type CA-602, with a maximum sensitivity of 5 ma for a stress of $100 \cdot 10^{-6}$ and with a maximum output current of 20 ma).

The firm Leader exhibited miniature printed circuit sweep generators type LGO-600 (frequency range 2-260 Mc) and an audio-oscillator LAG-65, consisting of a vibrator and a frequency meter. Its frequency range is 11 cps to 110 kc, and that of the frequency meter from 10 cps to 110 kc (in four bands), measurement error is ±1.5% for 10 cps to 11 kc and ±3% for 10 cps to 110 kc.

The Yokogawa electrotechnical plant exhibited an instrument for determining h-parameters of VTV-53 transistors at a frequency of 280 cps with an error of measurement in a common base circuit of 2.5% and in a common emitter circuit of 5%. They also showed a transistorized recording potentiometer type ER used in automatic control systems and having a range of 0-10 mv dc, a threshold sensitivity of 0.15%, an error of ±0.5% of the full scale deflection, input impedance of 5 kilohm, a speed of the chart movement of 25 mm/hr, with the chart automatically folding in the instrument. The portable dc ammeters and voltmeters type MPF grade 0.5 have a measuring range of 3 ma – 30 amp and 100 mv – 1,000 v respectively. The portable ac ammeters and voltmeters type SPF grade 0.5 have a range of 30 ma – 100 amp and 30 – 600 v, respectively. An instrument for measuring insulation resistance type L-5 has a range of 0-2,000 meg and an error of 10%.

Radio equipment and precision elements and components for radiotechnical and measuring instruments were also exhibited.

S. K.

COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

I. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTS AND PASSED FOR USE IN THE USSR

(Registered in August–September, 1960)
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Chamber interferometer, trade mark ShI-3, of the Novosibirsk Sovnarkhoz (Council of National Economy), State Register No. 1377-60.

Thermoelectric rack-mounted ammeters, trade mark T22, of the Omsk Sovnarkhoz. State Register No. 1378-60.

Thermoelectric rack-mounted ammeters, trade mark T23, of the Omsk Sovnarkhoz. State Register No. 1379-60.

Dc volt-hour meters, trade mark M641, of the Leningrad Sovnarkhoz. State Register No. 1380-60.

Dc volt-hour meters, trade mark M642, of the Leningrad Sovnarkhoz. State Register No. 1381-60.

Voltage transformers, trade mark NKF-220-58, of the Moscow City Sovnarkhoz. State Register No. 1382-60.

Resistance box, trade mark R34, of the Krasnodar Sovnarkhoz. State Register No. 1384-60.

Dc voltmeters and ammeters, trade mark M-151, of the Leningrad Sovnarkhoz. State Register No. 1385-60.

Dc miniature shockproof voltmeters and ammeters, trade mark M-145, of the Leningrad Sovnarkhoz. State Register No. 1386-60.

Rack-mounted voltmeters and ammeters, trade mark M-367, of the Krasnodar Sovnarkhoz. State Register No. 1387-60.

Pulse generators, trade mark GI-4M, of the Leningrad Sovnarkhoz. State Register No. 1388-60.

Pulse generators, trade mark GI-3M, of the Leningrad Sovnarkhoz. State Register No. 1389-60.

Decimeter band wavemeters of medium accuracy, trade mark VST-DM, of the Tatar Sovnarkhoz. State Register No. 1390-60.

Clinical electrical thermometers, trade mark TĖMP-60 of the Tatar Sovnarkhoz. State Register No. 1392-60.

Laboratory-type high-temperature thermometers, trade mark TL-36, of the Moscow regional Sovnarkhoz. State Register No. 1393-60.

Petrol pumps, trade mark 395M, of the Ministry of Automobile Transport and Motor Roads of the RSFSR. State Register No. 1394-60.

Urinometers with a glass cylinder, of the Moscow regional Sovnarkhoz. State Register No. 1395-60.

Electrical automatic gas analyzers, trade mark GÉB-U2, GÉM-U2 and GÉD-U3, of the State Committee of the Council of Ministers of the USSR for Chemistry. State Register No. 1396-60.

Thermistor small power meters, trade mark IMM-6, of the Gor'kii Sovnarkhoz. State Register No. 1397-60.

Electrical contacts, trade mark GK-2, of the Leningrad Sovnarkhoz. State Register No. 1398-60.

II. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER

Galvanometers type M91/A. State Register No. 449.

Voltammeters M80, M81. State Register No. 749.

Rack-mounted ammeters M730. State Register No. 849.

Rack-mounted voltmeters M730. State Register No. 850.

pH-Meters LP-5. State Register No. 995.

Galvanometers M21. State Register No. 1061.